A STUDY OF THE COSTS AND BENEFITS OF THE RESEARCH AND EXTENSION ASSOCIATED WITH THE INTEGRATED PEST MANAGEMENT PROGRAM ON APPLES IN ONTARIO.

M. Stemeroff and D.J. Madder

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Ontario Pesticides
Advisory Committee

Hon. Jim Bradley
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Ron McLeod
Deputy-Minister

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M. Stemeoff and D.J. Madder
Culice and Stemeroff Consultants
380 Woolwich Street
Guelph, Ontario, N1H 3W7
Canada

TERMS OF REFERENCE

The specific terms of reference of this contract between the Ontario Pesticides Advisory Committee of the Ontario Ministry of the Environment and Culice Incorporated are as follows:

1. provide a listing and quantitative analysis of the costs of research and extension associated with the integrated pest management program on apples in Ontario;

2. provide a listing and quantitative analysis of the benefits derived from the integrated pest management program on apples in Ontario;

3. compare the benefits to costs of integrated pest management, in order to establish the net economic return to integrated pest management on apples in Ontario;

4. establish a model for the analysis of the benefits and costs of integrated pest management in Ontario.

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SUMMARY

This report outlines the costs and benefits of research, development and extension of the Integrated Pest Management program used on apples in Ontario from 1965 to 1984. Within the limitations discussed in the text, the total research and extension costs from 1965 to 1984 were $14.4 million, and the total benefits due to reduced pesticide use were $58.5 million. Results indicate that benefits exceed costs by a ratio of between $4 to $1 and $3.2 to $1, depending upon the discount rate used in the analysis.

If growers strictly followed the recommendations of OMAF publication 360, the average cost of pest control (pesticide and application costs) on apples in Ontario in 1984 would be $1750/ha. If growers followed regional pest monitoring information, the costs would be $1307/ha, and if growers had either part or all of their orchard monitored, the average pest control costs was $1068/ha. Thus, the per hectare savings associated with regional monitoring were approximately $443/ha, and with intensive pest monitoring $682/ha. These savings will differ by region and by grower depending on the pest complex present and grower practices.

The standardized methodology developed and reported herein is applicable for evaluating the economic returns to IPM on other crops.

1. INTRODUCTION

Integrated pest management (IPM) is a philosophy of crop protection that has been defined as a multi-disciplinary, ecological approach to the management of pest populations, which utilizes a variety of control tactics compatibly in a single coordinated pest management system (Smith, 1978). It is based on the principle of optimum rather than maximum pest control and is a significant component of integrated crop management (agroecosystem management), which is intended to provide sustained agricultural production with minimal deleterious effects on society (Allan and Bath, 1980). IPM does not attempt to eradicate pests, but rather to maintain pest populations below those that cause damage of economic significance (Luckmann and Metcalf, 1982). Its primary goal is not to eliminate the use of pesticides but to rather use the best combination of control tactics to produce a stable agroecosystem. Within this context, pesticide use is often reduced when growers adopt IPM, as pesticides are used only when necessary and not on an insurance basis.

In reality, an IPM program based on true economic injury levels and economic thresholds with cost effective and practical monitoring technology does not, as yet, exist in North America (Poston et al. 1983). The programs which have been implemented are, to a major extent, pest monitoring programs and not true IPM programs. These programs monitor pest populations and use economic thresholds (nominal or simple) to identify potential pest problems. However, in many instances pesticides are often the only tactic available for pest control. As part of an IPM program, these pesticide applications are timed for optimum effect, are used judiciously, and chosen to delay the development of pesticide resistance.

Within this report, the term IPM is considered to be equivalent to pest monitoring. It is recognized that these terms are, by definition, quite different. However, for practical use within the context of extension in Ontario, pest monitoring has been considered synonymous with IPM.

1.1 INTEGRATED PEST MANAGEMENT IN CANADA

In Canada, the first use of the IPM philosophy was on apples in the Annapolis Valley of Nova Scotia in the early 1950's. Dr. A. D. Pickett and his colleagues at the Agriculture Canada Research Station in Kentville, N.S., recognized that while the regular use of DDT in orchards was controlling some pests effectively, other pests not previously a problem were beginning to cause significant damage. As a result, these workers developed a "modified spray program" that permitted parasites and predators to function as natural control agents in orchards, while using selective pesticides to control those pests that were not controlled by natural factors (Pickett, 1949).

IPM in Canada did not develop beyond the apple orchards in Nova Scotia until the late 1960's when problems associated with the intensive use of pesticides in orchards became more apparent in Ontario, Quebec and British Columbia. Research into the development of IPM programs in apples commenced in the late 1960's, with implementation of IPM commencing in Ontario in the early 1970's. In 1969, a research project was initiated by Agriculture Canada in the Georgian Bay region to study the feasibility of IPM on apples in Ontario. The aims were: a) to assess if the available pest monitoring methods were

practical; b) to determine if pesticide use could be reduced; and, c) to determine if the cost of the pest monitoring techniques could be recovered from reduced pest control costs. This project proved successful on all points, and as a result, further implementation of IPM on apples was initiated by the Ontario Ministry of Agriculture and Food. In 1975, the IPM program was expanded into other apple growing regions including Prince Edward, Northumberland and Durham counties, and by 1982 it was estimated that 97% of the total apple hectarage in Ontario had access to and used IPM information.

At the current time, all pest monitoring information is compiled in Simcoe Ontario, where a provincial "pest alert" system has been developed (OMAF, 1984b). Pest alerts are sent to extension horticulturists, who then disseminate information regarding pest populations and timing of applications to all apple growers via a network of 14 agri-phones and/or by grower newsletters.

Regional recommendations based upon pest monitoring information are available to all growers. In addition to the regional recommendations, site specific recommendations are available to growers who pay for this service. Growers may have a portion, or all, of their orchard monitored and recommendations made directly to them based on this information. Growers receiving these specific recommendations may not apply a pesticide when it is recommended within the region, or the grower may apply pesticides at slightly altered times as compared to the regional recommendations.

1.2 BENEFITS OF INTEGRATED PEST MANAGEMENT

The potential benefits of the IPM program in apples touch all facets of society in Ontario. Growers benefit from reduced risk from losses caused by pests (Hall, 1977) and from reduced pest control costs (Tew et al., 1982). Agrochemical companies may benefit from the more judicious use of pesticides as the development of pesticide resistance may be delayed. Society, in general, benefits by reductions in pesticide contamination of the environment (Flint and van den Bosch, 1981; Huffacker et al., 1978) and the development of a more stable agroecosystem. It is difficult, if not impossible, to quantify the returns to IPM, except within the context of reduced production costs associated with reduced pesticide use. As a result, the study reported herein must focus on the returns to investment in IPM as a function of reduced pesticide use. This does not indicate that the other benefits listed above are not significant, but rather that they cannot be reliably quantified.

Economic studies have evaluated specific insect control methods and techniques used on onions, apples, and potatoes in Ontario (Stemeroff, 1981; Stemeroff and George, 1983; Pfeiffer and Haack, 1979), where only direct on-farm costs and benefits were considered. Pfeiffer and Haack (1979) conducted a cost-efficiency study comparing growers using pest monitoring services with those not using the services. Based upon 92 sets of spray records from 16 farm interviews, results indicate that the average cost savings with pest-monitoring was $100 per hectare. The net benefit (cost savings - monitoring costs) was estimated to be $60 per hectare. However, these studies did not consider the development, implementation and maintenance costs of the actual IPM programs in Ontario.

1.3 OBJECTIVES

The purpose of this study was threefold: 1) to quantify the costs and benefits of the research and extension associated with the integrated pest management program currently in place for apples in Ontario; 2) to provide a general model that could be applied to other crops in Canada, for assessing the economic return to IPM programs.

2. METHODS

A financial accounting approach based upon established benefit/cost assessment procedures was used in this study to assess the economic returns to research and extension associated with IPM on apples in Ontario, (Thompson, 1983; Treasury Board of Canada, 1976).

2.1 REQUIREMENTS FOR ANALYSIS

The analysis required the following three operations: 1. the types or levels of pest control practiced in Ontario apple orchards were identified; 2. the costs and benefits associated with each level were quantified; and 3. the costs and benefits for each level were compared.

1. Four levels of pest control used on apples in Ontario were identified.

   Level 1: Growers who apply pesticides based only upon information provided by OMAF Publication 360.

   Level 2: Growers who apply pesticides based upon information contained in Pub. 360, and regional "pest alert" information based upon regional pest monitoring. Growers using this level would obtain monitoring information primarily from OMAF agri-phones, with summary updates in grower newsletters.

   Level 3: Growers who apply pesticides based upon Pub. 360, regional monitoring information, and site-specific information supplied by scouts who monitor a portion of the grower's orchard.

Level 4: Growers who apply pesticides based upon Pub. 360, and full orchard monitoring. These growers would have a scout monitor their complete orchard and supply specific information on when to use pest control measures. Such pest monitoring information would be unique to each grower's orchard. Currently this is an experimental program and is used on a very small portion of the hectarage.

For the purposes of this report, all of these levels are referred to as levels of pest control, however levels 2 to 4 are considered to be IPM.

2. Annual costs and benefits of pest control from 1965 to 1984 were complied for each pest control level (see Table 1).

Table 1: Costs and Benefits of Pest Control Levels

COSTS	BENEFITS
research costs extension costs pesticide costs (insecticides, acaricides, and fungicides*) application costs monitoring costs	the difference in pesticide and application costs between Level 1 and Levels 2, 3, and 4

* herbicide use and costs are equal for all pest control levels (W. Roberts, pers. comm.)

The benefits derived from the use of IPM (at either level 2,3, or 4) are the cost savings in pesticide and application costs, compared to the "potential" costs if growers strictly followed pest control level 1, i.e., OMAF pub. 360. It is recognized that few, if any, apple growers currently follow OMAF pub. 360, nor it is likely that growers followed it closely prior to the introduction of IPM on

apples in Ontario (Hagley, pers. comm.). However, growers used it as a guideline and adopted it to their own pest control practices. Publication 360 is used here as a benchmark from which to compare cost savings as it is the only benchmark available and is based on the concept of applying pesticides on a schedule rather than pest monitoring information.

According to discussions with growers, research and extension personnel, Publication 360 presents a worst-case scenario for insecticide and acaricide use, and somewhat underestimates fungicide use in terms of what would have occurred from 1965 to 1984 if IPM was not introduced (Roberts, Hagley, and Norfolk Fruit Growers Association, pers. comm). Thus, the analysis used in this study may overestimate the benefits in reduced pesticide use associated with IPM. However, it is not possible to know what would have occurred over the past 20 years if IPM had not been introduced. Recommended pesticide use might have increased to much greater levels than currently recommended in Publication 360, eg., due to the development of pesticide resistance. Thus, the recommendations in Publication 360 are considered a valid benchmark to compare pesticide use. It is realized that the actual pesticide use without IPM may have varied from 30% less, to 20% greater than that recommended in Publication 360. The results should be viewed with this in consideration.

3. Benefits and costs of each pest control level, as defined above, were used to calculate benefit/cost ratios and an estimation of economic return to investment in IPM on apples in Ontario.

2.2 DATA AND INFORMATION SOURCES

Data for the above analyses were collected from a variety of sources. Information concerning pesticide use by pest control level was provided by W. Roberts, OMAF, Guelph Ontario; E. Hagley, Agri. Canada, Vineland Ontario; Norfolk Fruit Grower's Association, Simcoe Ontario; B. Ells, OMAF Bowmanville Ontario; and C. Hunter, OMAF, Simcoe, Ontario. Application records for Georgian Bay apple growers were obtained from W. Roberts, and confirmation of the validity of the figures and analysis was provided by the Norfolk Fruit Growers Association (Appendix A). Information concerning the costs of the pesticides was provided by agro-chemical companies. Estimations of the extension costs associated with pest control in apples were provided by W. Roberts and R. Shaw, OMAF, Guelph, Ontario. Information concerning the costs of research concerning pest control in apples was provided by E. Hagley, Agr. Can., Vineland; and the Inventory of Pome-Fruit Research in Ontario, was supplied by D. Elfving, OMAF, Simcoe.

2.3 METHOD OF ANALYSIS

All costs (research, extension, pesticide, application, and monitoring) were listed on a yearly basis from 1965 to 1984, and expressed in constant 1982 dollars, thereby eliminating the influence of inflation. Economists often refer to such a practice as expressing costs in "real" dollars as opposed to "nominal" dollars.

Tables comparing costs and benefits (cost savings), although all expressed in real dollars, required further accounting for "the time value of money", or alternatively the "opportunity cost of money".

This recognizes that beyond adjusting figures for inflation, equal monetary values associated with different years are not equal in an economic sense, because one dollar spent last year could have earned interest, or appreciated in value if spent elsewhere, compared to one dollar being spent now. It is this loss in earning potential of money once invested in a program, that must be added to our accounting of costs and benefits. The process used by economists to do this is "discounting" (Thompson, 1983).

The costs of IPM and its associated benefits are discounted to a base year (1965), using the following discounting formula:

$$PV + \frac{T}{(1+r)^n}$$

where:

PV = present value of some future monetary value,

T = future monetary value,

r = discount factor, and

n = number of years from base year.

The discount factor (r) is a number relating value in one year to value in the next or past year. The discount factor is commonly determined as the interest rate at which the decision-maker can invest or borrow money. Usually, if all costs and benefits are expressed in real dollars, the discount factor (r) is between 0 to 8 percent, depending upon the researchers discretion. There is no method for determining the most appropriate factor to use. Thus, the analysis used here will employ a range of discount factors, (i.e. 0, 3, 5, and 8%).

The present value of costs (PVC) from IPM, and the present value of benefits (PVB), are combined in a ratio to obtain the benefit/cost ratio. The formula used in this ratio is:

$$B/C = \frac{PVB}{PVC}$$

A final economic measure of importance is the "internal rate of return" (IRR). It is the discount rate of interest (r) that exactly results in a B/C ratio of one to one. The interpretation of the IRR is similar to interpretation of interest earnings on a regular bank savings account - namely, it indicates the "yield" of money. IRR results are expressed in percentage terms.

All cost and benefit calculations were performed with the use of Lotus 1-2-3, an electronic spreadsheet, used on a micro-computer.

3. RESULTS

3.1 APPLE PRODUCTION SETTING

In 1983, Ontario produced approximately 165,000 tonnes of commercial apples (fresh and processing), constituting 25 to 30% of Canadian production. The farmgate value of Ontario's production was $37 million, which accounts for about 0.7% of total farm cash receipts in the province (OMAF, 1983). Many varieties of apples are grown in Ontario, the most commonly grown including McIntosh, Red Delicious, Greening, Idared, Northern Spy, and Winesaps.

Within Ontario, Niagara and Haldimand-Norfolk counties produce the greatest proportion of apples in the province, (approx. 50%). Grey county is the second largest apple producing area, while Western Ontario accounts for approximately 30 - 35% of total production. In Central and Eastern Ontario, production is dispersed over many counties, however, the largest concentration of production occurs in Northumberland county. All of the major apple producing regions in Ontario have one common characteristic: they are located adjacent to large bodies of water. The effect of this is a moderated climate with conditions conducive to apple production (Campbell, 1983).

Of the total apple production, approximately 40 - 50% goes to fresh markets, and the remainder to processing markets. In the past, fresh market apples have commanded higher prices than processing apples, by as much as three fold (Statistics Canada, Cansim Matrices 1393, 5587, 5588). However, over the past decade the value of processing apples has increased relative to fresh market prices (Campbell, 1983). This is probably a reflection of increased consumer demand for apple juice and other apple products.

A suggested minimum price is set yearly by the Ontario Apple Commission. Apple prices fluctuate significantly from one year to the next, depending upon market conditions of supply and demand throughout North America. Generally, Ontario apple producers exert only a minor influence on this price-setting mechanism, because Ontario produces only a small share of the total North American production in any one year.

The total costs of production per hectare in Ontario, broken down into standard and size-controlled tree operations, are presented in Table 2. The total cost of production per hectare is $3,788 for standard and $4,224 for size controlled orchards. Total pesticide costs (insecticides, fungicides, acaricides, and herbicides) comprise 18% of total variable costs in standard size orchards, and 19% of total variable costs in size-controlled orchards. When expressed as a percentage of total costs (fixed plus variable costs), pesticides comprise 14% and 15% of total costs of production for standard and size-controlled orchards respectively. Thus, pesticides comprise a major component of production costs. Only labour costs (primarily harvesting labour) are greater than the costs of pesticides.

3.2 COSTS, BENEFITS AND ECONOMIC RETURNS TO INTEGRATED PEST MANAGEMENT

The tabulation of all costs, benefits and economic returns associated with each level of pest control are presented in this section. The first subsection presents an accounting of all research and extension costs associated with pest control (levels 1 to 4) on

apples in Ontario. The second subsection presents an accounting of the benefits (cost-savings) from the introduction of IPM, (levels 2 to 4). The final sub-section analyzes the benefit/cost ratio and economic returns to investment (IRR) in IPM.

TABLE 2: Costs of Production Per Hectare For Apples in Ontario

	Standard Trees	Size Controlled Trees
Variable Costs:		
Hired labour: Harvesting	1,339.5	1,185.0
Other	261.8	496.5
Fertilizer	59.8	94.3
Pesticides*	650.0	675.0
Tractor operating costs	129.5	128.3
Machine operating costs	126.8	104.8
Bin useage	192.5	295.0
O.A.M.C. fees	58.0	59.0
Crop and liability insurance	93.0	122.5
Miscellaneous costs	24.8	39.3
Interest on operating capital	100.0	112.5
Total Variable Costs:	3,035.7	3,312.2
Fixed Costs:		
Operator labour	341.3	325.0
Tractor use	70.0	96.5
Machine use	110.5	125.0
Land investment	205.3	341.3
Taxes	25.0	23.8
Total Fixed Costs	751.1	911.6
Total Costs	3,787.8	4,223.8

* Insecticides, Acaricides and Fungicides
Source: OMAF Agdex, 1985.

3.2.1 COSTS

Research Costs

The number of Person Years (PY) devoted to pest control research for each level of pest control on apples in Ontario, from 1965 to 1984, is presented in Table 3. Level 1 research, includes all research required for support and publication of OMAF Publication 360. In 1965, 0.2 PY was associated with level 1; this increased to approximately 1.0 PY in 1981 and subsequently declined to 0.79 PY by 1984. Over the 20 year period, a total of 15.45 PY were employed in level 1 research.

Research PY devoted to levels 2, 3, and 4, (IPM) cannot be separated as the research and technology used in each of these levels are the same. The difference between levels depends on whether the recommendations are made on a regional, partial orchard, or entire orchard basis. Thus, only one figure for research PY for levels 2-4 for each year is presented. In 1965, 0.8 PY were employed in IPM research. This number increased to 4.36 PY by 1981 and subsequently declined to 3.16 PY by 1984. Over the 20 year period, a total of 61.8 PY were employed in IPM research on apples in Ontario.

TABLE 3: Person Years Devoted to Research and Extension Concerning Pest Control on Apples in Ontario from 1965 to 1984*

Year	Research		Extension-Professional			Extension-Scouts		TOTAL
	Level 1	Level 2-4	Level 1	Level 2	Level 3	Level 2	Level 3	
1965	0.20	0.80	1.00	0.00	0.00	0.00	0.00	2.00
1966	0.20	0.80	1.00	0.00	0.00	0.00	0.00	2.00
1967	0.20	0.80	1.00	0.00	0.00	0.00	0.00	2.00
1968	0.60	2.40	1.00	0.00	0.00	0.00	0.00	4.00
1969	0.70	2.80	1.00	0.00	0.00	0.00	0.00	4.50
1970	0.80	3.20	1.00	2.00	0.00	0.00	0.00	7.00
1971	0.80	3.20	0.75	2.10	0.00	0.00	0.00	6.85
1972	0.90	3.60	0.75	2.20	0.00	0.00	0.00	7.45
1973	0.90	3.60	0.75	2.30	0.00	0.00	0.00	7.55
1974	0.90	3.60	0.75	2.40	0.00	0.00	0.00	7.65
1975	1.00	4.00	0.75	2.50	0.00	0.00	0.00	8.25
1976	0.99	3.96	0.75	3.00	0.00	0.00	0.00	8.70
1977	0.97	3.88	0.50	4.00	0.00	1.33	0.00	10.68
1978	0.95	3.80	0.50	4.50	0.00	2.00	0.00	11.75
1979	0.93	3.72	0.50	5.00	0.00	2.00	0.00	12.15
1980	0.79	3.16	0.50	5.00	3.00	1.00	1.00	14.45
1981	1.09	4.36	0.35	5.00	3.00	1.34	1.33	16.47
1982	0.95	3.80	0.35	5.00	3.00	1.59	1.58	16.27
1983	0.79	3.16	0.35	5.00	3.00	2.09	2.08	16.47
1984	0.79	3.16	0.35	5.00	3.00	2.50	2.50	17.30
TOTAL	15.45	61.80	13.90	55.00	15.00	13.85	8.49	183.49

* No extension costs have been incurred for level 4.

The annual costs of research for each level are presented in Table 4. The annual research costs were calculated by multiplying the appropriate PY (Table 3) by $120,000. This cost per PY, is the figure used by Agriculture Canada and OMAF (1984), and includes the average salaries of one professional researcher plus associated support staff, equipment, transportation, and overhead. The total cost of research for level 1, from 1965 to 1984, was $1.9 million. For levels 2-4, the total research cost, during the same period, was $7.4 million.

While some of the research done before 1964 was undoubtedly used in the development of the IPM technology currently used in apples, it is impossible to identify the specific number of research PY involved. In part, this pre-1964 investment in IPM research is accounted for by the inclusion of costs of IPM research in recent years, e.g. since 1980, which has not as yet been implemented. Generally, two to eight years is required for research results to be fully implemented (Brinkman and Prentice, 1981). Similarly, research performed in other apple producing regions may have provided benefits to the IPM program used in Ontario, however, it is not possible to quantify these "spillover" benefits. It must be assumed that the spillover benefits from other research programs are equal to the spillover benefits to other programs derived from the research program in Ontario.

TABLE 4: Person Year Costs Related to Research and Extension Concerning Pest Control on Apples in Ontario from 1965 to 1984.

Year	Research		Extension-Professional			Extention-Scouts		TOTAL
	Level 1	Level 2-4	Level 1	Level 2	Level 3	Level 2	Level 3	
1965	$ 24,000	$ 96,000	$ 60,000	$ 0	$ 0	$ 0	$ 0	$ 180,000
1966	24,000	96,000	60,000	0	0	0	0	180,000
1967	24,000	96,000	60,000	0	0	0	0	180,000
1968	72,000	288,000	60,000	0	0	0	0	420,000
1969	84,000	336,000	60,000	0	0	0	0	480,000
1970	96,000	384,000	60,000	120,000	0	0	0	660,000
1971	96,000	384,000	45,000	126,000	0	0	0	651,000
1972	108,000	432,000	45,000	132,000	0	0	0	717,000
1973	108,000	432,000	45,000	138,000	0	0	0	723,000
1974	108,000	432,000	45,000	144,000	0	0	0	729,000
1975	120,000	480,000	45,000	150,000	0	0	0	795,000
1976	118,800	475,200	45,000	180,000	0	0	0	819,000
1977	116,400	465,600	30,000	240,000	0	5,985	0	857,985
1978	114,000	456,000	30,000	270,000	0	9,000	0	879,000
1979	111,600	446,400	30,000	300,000	0	9,000	0	897,000
1980	94,800	379,200	30,000	300,000	180,000	4,500	4,500	993,000
1981	130,800	523,200	21,000	300,000	180,000	6,030	5,985	1,167,015
1982	114,000	456,000	21,000	300,000	180,000	7,155	7,110	1,085,265
1983	94,800	379,200	21,000	300,000	180,000	9,405	9,360	993,765
1984	94,800	379,200	21,000	300,000	180,000	11,250	11,250	997,500
TOTAL	$1,854,000	$7,416,000	$834,000	$3,300,000	$900,000	$62,325	$38,205	$14,404,530

EXTENSION COSTS

Professional Person Years

The number of professional extension PY devoted to pest control in apples in Ontario is listed in Table 3. From 1965 to 1969, one PY was devoted to pest control, all of which was in the level 1 category. From 1970 extension PY devoted to level 1 pest control declined to that it was 0.35 PY by 1984. Extension PY devoted to level 2 increased from 2 in 1970 to 5 by 1984. Level 3 extension, which commenced in 1980 with 3 PY, remained at this number through to 1984. No extension PY have been devoted to level 4 pest control, as it is in a preliminary (experimental) phase, and its extension cost is currently accounted for in level 4 research costs.

The total professional extension PY from 1965 to 1984 associated with level 1 totalled 13,9; with level 2, 55.0; and with level 3, 15.0.

The costs of professional extension PY are presented in Table 4. To obtain the figures shown, the appropriate number of extension PY (Table 3) were multiplied by $60,000. This figure, used by OMAF, represents the average annual cost for salaries of professional extension workers and their associated support staff, equipment, transportation, and share of overhead. The total cost of professional extension for level 1, during 1965-84, was $0.8 million; for level 2, $3.3 million; and for level 3, $0.9 million.

Scout Person Years

Scouts travel to individual grower's orchards to collect pest monitoring data. It is this information, collected by scouts, and compiled by extension personnel which provides much of the information upon which pest alerts are given on the agri-phone. The information collected by scouts also provides the basis for specific orchard recommendations.

The annual number of scout PY employed is reported in Table 3. To date, scouts have been employed for levels 2 and 3. The costs of scouts for level four is included in research costs. In 1977, 1.33 scout PY were employed in level 2. This number gradually increased to 2.5 by 1984. In 1980, one scout PY was used for level 3 pest control. This number increased to 2.5 by 1984. The total number of scout PY employed during the study period was 15.0 for level 2, and 13.85 for level 3.

The total scout costs are reported in Table 4. The cost for scouts was calculated by multiplying the appropriate scout PY by $4,500. This figure, supplied by OMAF Extension Branch, incorporates the scout's salary, associated transportation costs, monitoring materials, and overhead. The total scouting costs from 1965 - 1984 were $62,000 for level 2 and $38,000 for level 3.

Total Research and Extension Costs

Summing across all levels of annual research, professional extension, and scouting costs, the total costs associated with research and extension for pest control on apples in Ontario is obtained (Table 4 - last column). The total cost for the period 1965-1984 is $14.4 million, most of which consists of research costs. (A more detailed discussion is presented in Section 3.2.3.)

3.2.2 Benefits

To quantify the value of reduced pesticide use associated with IPM it was necessary to determine the differences in spray regimes between the four pest control levels. Appendix Tables 1 to 3 provide a schematic listing of the insecticides, acaricides, and fungicides (respectively) what were registered and recommended for use in OMAF Publication 360 from 1965 to 1984. The relative annual frequencies of use of these pesticides were determined for each pest control level for each year during the period 1965 to 1984. Appendix Tables 4 to 6 provide listings of the annual applications of insecticides usually used under pest control level 1, level 2, and levels 3-4, respectively. (Annual applications of pesticides are currently the same for levels 3 and 4). Appendix Tables 7 to 9 provide listings of the annual applications of acaricides, and Appendix Tables 10 to 12 provide the same information for fungicides. A summary of the results indicating the annual applications of insecticides, acaricides, and fungicides by pest control level is presented in Table 5.

The annual frequency of use multiplied by the application rate and the unit cost, provided the total costs for each pesticide in each year. To provide the total pesticide costs, the costs of each of the insecticides, acaricides and fungicides were then summed for each year and pest control level. Pesticide prices were obtained from company-supplied information to OMAF, Plant Industry Branch (Pesticides For Fruits, Vegetables and Field Crops in Ontario, annual internal document). The rates of pesticide applications were obtained from OMAF Publication 360.

The annual insecticide costs per hectare for each level of pest control are presented in Appendix Tables 13 to 15 and summarized in Figure 1. All costs are expressed in constant 1982 dollars.

TABLE 5: Comparison of Annual Pesticide Application Frequencies for Each Pest Control Level on Apples in Ontario 1965-1984

	INSECTICIDES			ACARACIDES			FUNGICIDES		
LEVELS	1	2	3-4*	1	2	3-4*	1	2	3-4*
YEAR									
1965	8.0	8.0	8.0	3.0	3.0	3.0	13.5	13.5	13.5
1966	9.0	9.0	9.0	3.0	3.0	3.0	13.45	13.45	13.45
1967	8.0	8.0	8.0	3.0	3.0	3.0	13.25	13.25	13.25
1968	9.0	9.0	9.0	3.0	3.0	3.0	13.25	13.25	13.25
1969	8.0	8.0	8.0	3.0	3.0	1.5	13.0	13.0	13.25
1970	8.0	8.0	8.0	3.0	2.0	1.25	13.0	10.0	13.0
1971	10.0	5.0	5.0	3.0	2.0	1.0	13.0	10.0	10.0
1972	10.0	5.0	5.0	3.0	2.0	1.0	13.0	10.0	10.0
1973	10.0	5.0	5.0	3.0	2.0	1.0	13.0	10.0	10.0
1974	10.0	5.0	5.0	3.0	1.5	1.0	13.0	10.0	10.0
1975	10.0	5.0	5.0	3.0	1.5	1.0	13.0	10.0	9.0
1976	10.0	6.0	5.0	3.0	1.5	1.0	13.0	10.0	9.0
1977	10.0	5.0	5.0	3.0	1.5	1.0	13.0	10.0	9.0
1978	10.0	6.0	5.0	3.0	1.5	1.0	13.0	10.0	9.0
1979	10.0	5.0	5.0	3.5	1.5	1.0	13.0	10.0	9.0
1980	10.0	6.0	5.0	4.0	1.0	1.0	13.0	10.0	9.0
1981	10.0	5.0	5.0	4.0	2.25	1.5	13.0	10.0	9.0
1982	10.0	6.0	5.0	4.0	2.5	1.75	13.0	10.0	9.0
1983	10.0	6.0	5.0	4.0	3.0	2.0	13.0	10.0	9.0
1984	10.0	6.0	5.0	4.0	3.25	2.0	13.0	10.0	9.0

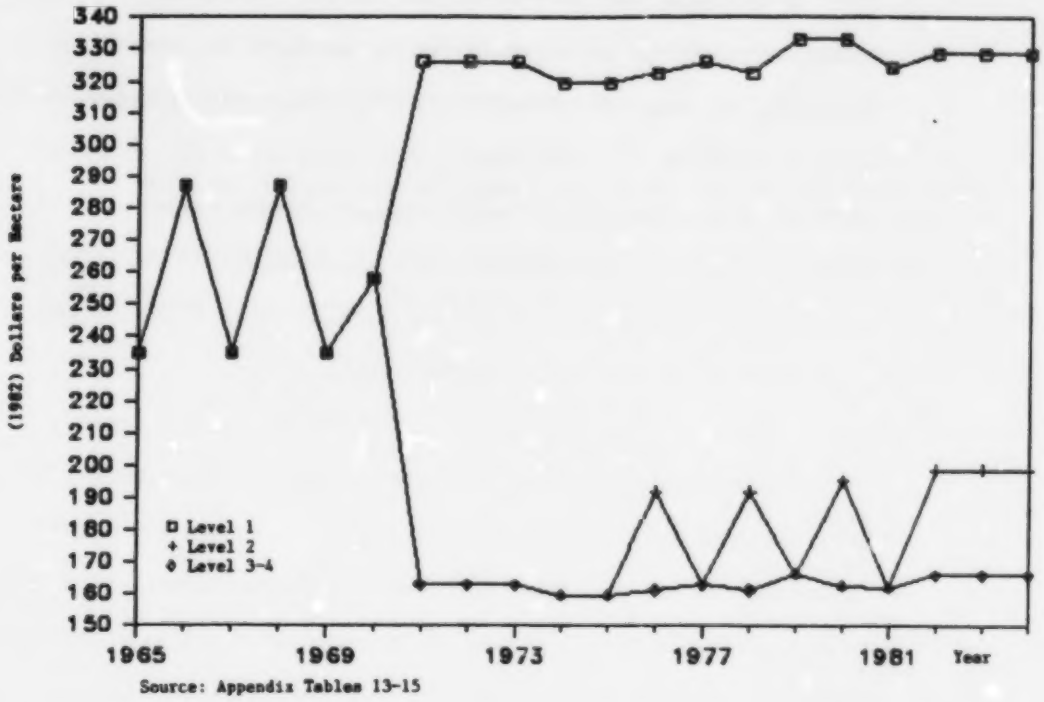
* levels 3 and 4 are the same.
Source: Appendix Tables 4 - 12

Large differences in insecticide costs exist between level 1 and level 2 (approximately $140/hectare). However, the cost differential between level 2 and level 3 - 4 is relatively small, (approximately $15/hectare on average). Prior to 1970, all levels of insecticide costs were equal as the influence of IPM was evident only after the initiation of implementation in 1969. Insecticide costs in levels 2-4 have remained at relatively low levels since 1970 with only minor year-to-year fluctuations.

The annual acaricide costs per hectare for each pest control level are presented in Appendix Tables 16 to 18 and summarized in Figure 2. As with insecticides, the cost differentials for acaricides between level 1 and level 2 are large (from $50 to $300/-hectare, with an average of approximately $125/hectare). In addition, the cost differentials between level 2 and level 3-4 are larger than those evident for insecticides ($0 to $100/hectare, with an average of approximately $50/hectare).

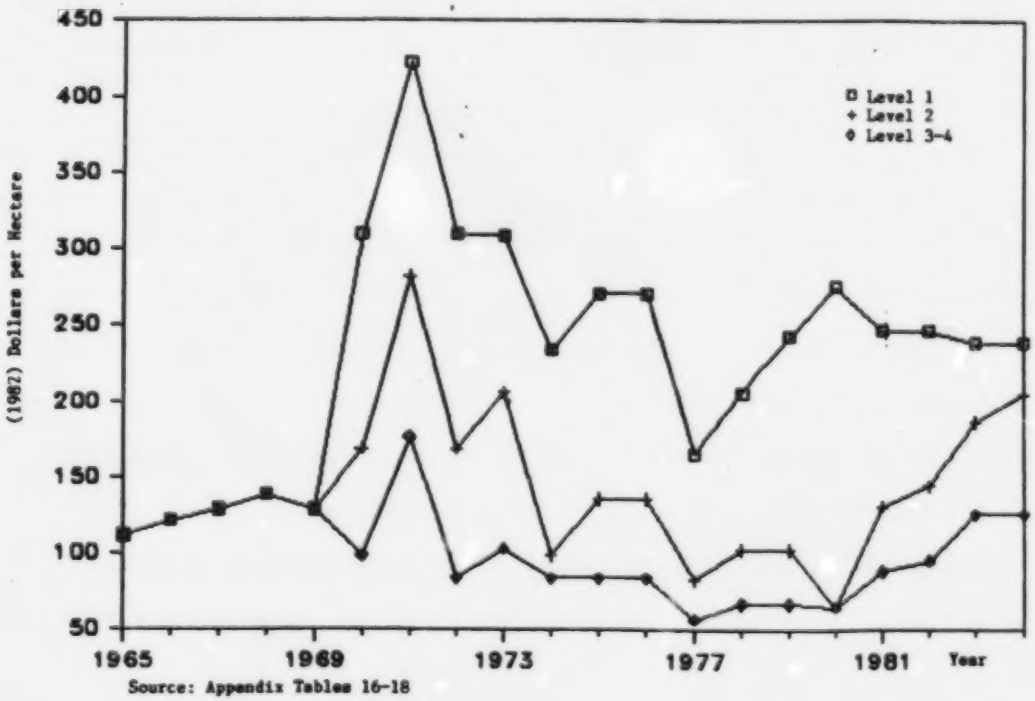
The annual fungicide costs per hectare for each pest control level are presented in Appendix Tables 19 to 21 and summarized in Figure 3. The average cost differential between level 1 and level 2 is approximately $140/hectare, and the cost differential between level 2 and levels 3-4 is approximately $45/hectare.

Figure 1: Annual Insecticide Costs on Apples in Ontario by Pest Control Level, 1965-84



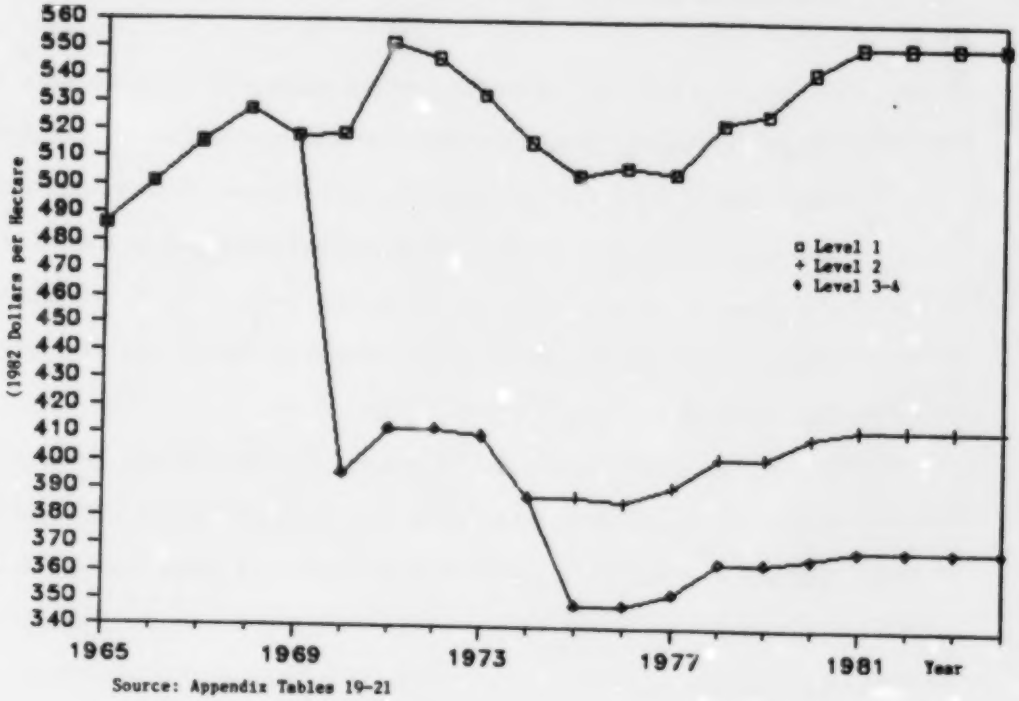
Source: Appendix Tables 13-15

Figure 2: Annual Acaricide Costs On Apples in Ontario by Pest Control Level, 1965 - 84



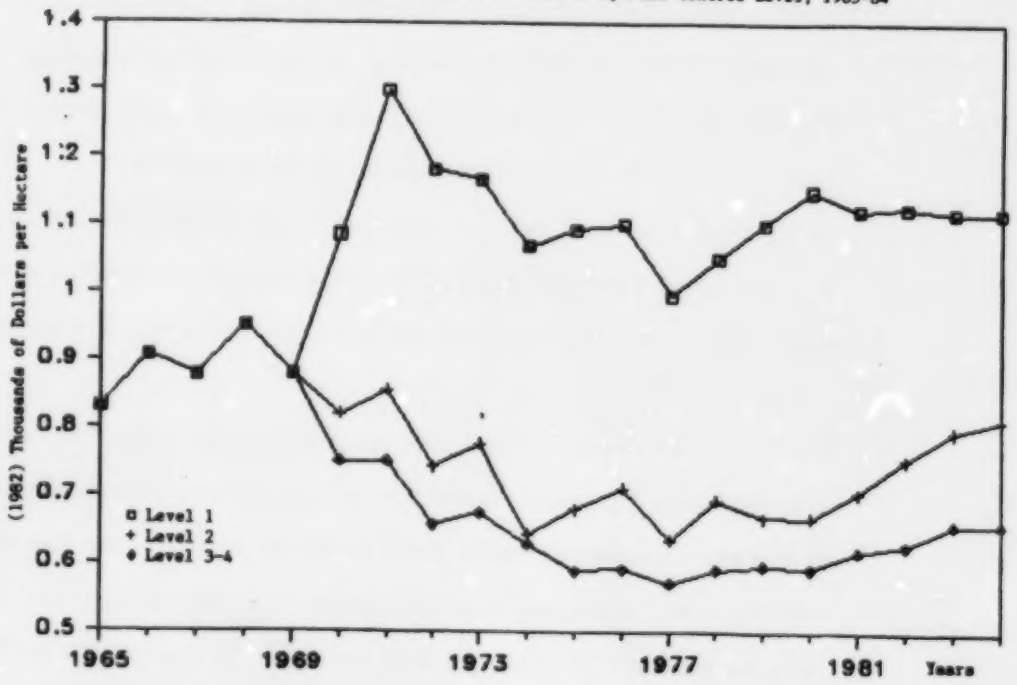
Source: Appendix Tables 16-18

Figure 3: Annual Fungicide Costs on Apples in Ontario by Pest Control Level, 1965-84



Source: Appendix Tables 19-21

Figure 4: Total Pesticide Costs on Apples in Ontario by Pest Control Level, 1965-84



Cost-Savings With Integrated Pest Management

Total pesticide costs per/hectare each year for each pest control level, derived by totalling the insecticide, acaricide, and fungicide costs are illustrated in Figure 4. From these it is evident that pesticide costs are substantially reduced when IPM is used (levels 2 - 4 compared with level 1). The average annual total pesticide cost differential between level 1 and levels 2 - 4 is approximately $400/hectare.

The results presented in Figure 4 represent differences in pesticide costs only. The reduction in pesticide use associated with IPM also causes a reduction in the number of pesticide applications required. The total number of pesticide applications per year for each pest control level are presented in Appendix Table 22. Insecticides, acaricides, and fungicides may occasionally be applied together in tank mixes, thus saving the grower multiple application costs. The number of pesticide applications is adjusted to reflect the common practice of tank mixing, as per consultation with W. Roberts (OMAF) and the Norfolk Fruit Growers Association (Simcoe). From 1965 to 1984, the total number of pesticide applications for level 1 pest control was 327; 260 for level 2; and 240 for levels 3-4. The costs (labour, fuel, and machinery depreciation) for each application in an orchard are estimated at approximately $37/hectare.

The total cost of pesticide application each year for each pest control level (Appendix Table 23) is the product of application frequencies (Appendix Table 22) multiplied by $37. For the period of 1965 to 1984, the total cost of application per hectare for level 1 pest control was $12,100; $9,600 for level 2; and $8,900 for levels 3-4.

The total pest control costs (pesticide and application costs) for each level of pest control each year are shown in Figure 5. The lines produced are similar to those in Figure 4, however the vertical (cost) scale is different. The average annual cost differential between level 1 and level 2 is approximately $550/hectare, and between level 1 and level 2 is approximately $750/hectare.

To assess total cost-savings to apple production in Ontario, it is necessary to know the number of hectares associated with each level of pest control each year, from 1965 to 1984. The hectarage associated with all four levels of pest control on apples for this period is presented in Table 6. In 1970, 2,800 hectares of apple orchards received level 2 treatment, 80 hectares received level 3, and 8,300 hectares received level 1. By 1984, the number of apple hectares increased to approximately 10,000 for level 2, and 3,600 for level 3. In 1980, 20 hectares of apple orchards received level 4 pest control with five additional hectares in 1983-4. By 1984, a very small hectarage was using level 1, i.e., approximately 2% of the total hectarage (Stemeroff and George, 1983; Roberts 1984).

Figure 5: Total Pesticide plus Application Cost by Pest Control Level on Apples in Ontario 1965-84

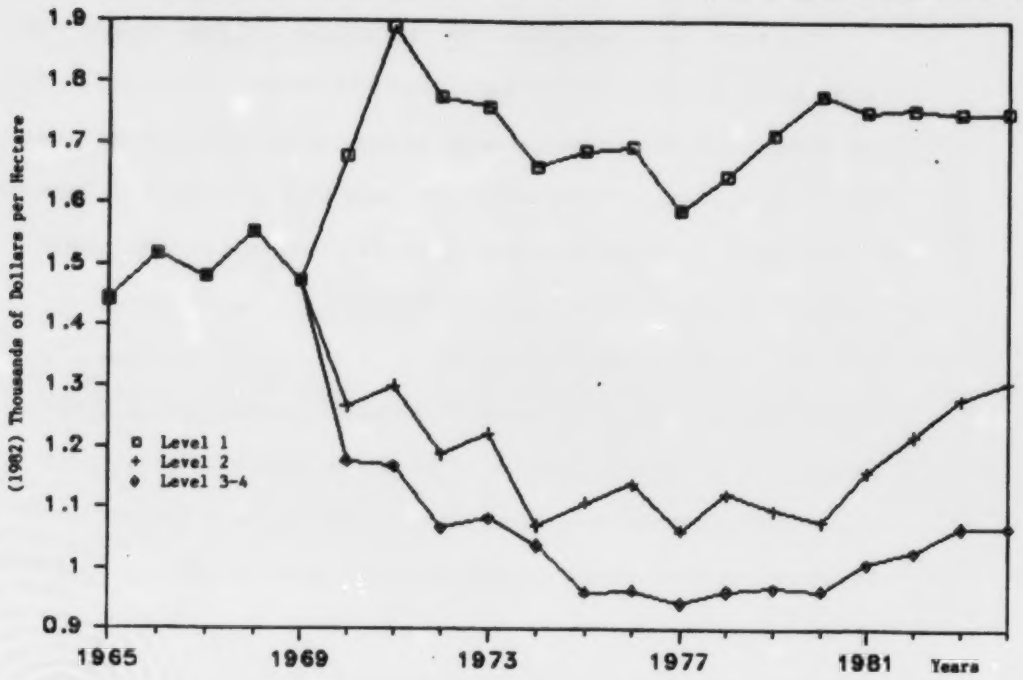


Figure 6: Comparison of Pest Control Costs (Pesticide plus Application) Between Pub. 360 and IPM

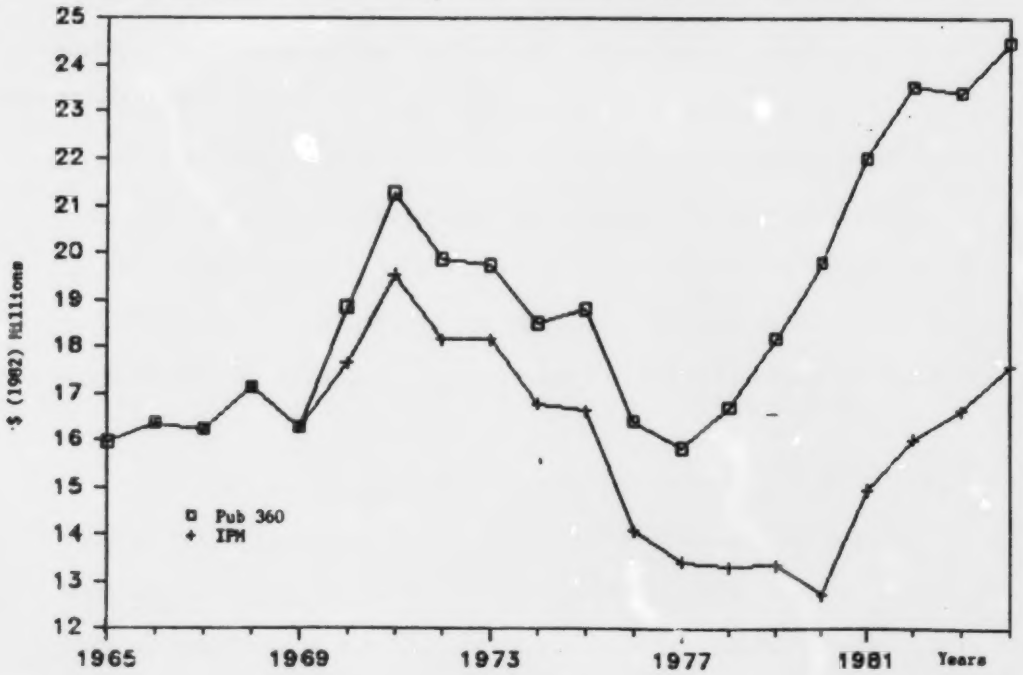


TABLE 6: Hectarage Associated with Each Level of Pest Control on Apples in Ontario, 1965 - 1984

Year	Level 1	Level 2	Level 3	Level 4	TOTAL
1965	11,062				11,062
1966	10,778				10,778
1967	10,961				10,961
1968	11,034				11,034
1969	10,969		80		11,049
1970	8,324	2,832	80		11,236
1971	8,329	2,832	80		11,241
1972	8,293	2,832	80		11,205
1973	8,304	2,832	80		11,216
1974	8,233	2,832	80		11,145
1975	7,442	3,560	150		11,152
1976	5,598	3,810	280		9,688
1977	5,469	4,100	400		9,969
1978	3,828	5,740	600		10,168
1979	2,942	6,866	810		10,618
1980	1,281	8,500	1,319	20	11,120
1981	1,198	9,150	2,214	20	12,582
1982	326	10,530	2,540	20	13,416
1983	311	10,057	3,000	25	13,393
1984	311	10,057	3,600	25	13,393

LEVEL 1 = Spray schedule according to OMAF Pub. 360 only
LEVEL 2 = OMAF Pub. 360 plus Agri-Phone information
LEVEL 3 = Partial orchard monitoring plus Agri-Phone
LEVEL 4 = Entire orchard monitoring plus Agri-Phone.
Source: Roberts, Pers. Comm.

Given the annual hectarage of each level of pest control, and the total pest control per hectare, the final step is to calculate what the total pest control cost for Ontario would have been if IPM was not introduced, (Table 7 - column A); and compare that expenditure to the actual costs of pest control with the introduction of IPM (Table 7 - column E). Column A in Table 7 is derived from the multiplication of the total cost of pest control per hectare for level 1 (Appendix Table 24) by the total number of orchard hectares each year from 1965 to 1984 (Table 5). Actual, total pest control costs from 1965 to 1984 for apples in Ontario are derived from the multiplication of level 1 to 4 control costs per hectare (Appendix Table 24) by the respective hectares listed in Table 6 for each level of pest control.

TABLE 7: Comparison of Total Pest Control Costs ($ millions) Between Pub. 360 and IPM

Year	(A) Pub. 360	(B) Level 1	(C) Level 2	(D) Level 3-4	(E) Total IPM (B+C+D)
1965	16.0	16.0			16.0
1966	16.4	16.4			16.4
1967	16.2	16.2			16.2
1968	17.1	17.1			17.1
1969	16.2	16.2			16.2
1970	18.9	14.0	3.6	0.09	17.6
1971	21.3	15.8	3.7	0.09	19.5
1972	19.8	14.7	3.4	0.09	18.2
1973	19.7	14.6	3.5	0.09	18.2
1974	18.5	13.7	3.0	0.08	16.8
1975	18.8	12.6	3.9	0.10	16.6
1976	16.4	9.5	4.3	0.27	14.1
1977	15.8	8.7	4.4	0.38	13.5
1978	16.7	6.3	6.4	0.58	13.3
1979	18.2	5.0	7.5	0.78	13.3
1980	19.8	2.3	9.2	1.29	12.8
1981	22.0	2.1	10.6	2.25	15.0
1982	23.5	0.6	12.8	2.63	16.0
1983	23.4	0.5	12.9	3.23	16.6
1984	24.5	0.5	13.1	3.87	17.5

Column A represents the total cost of pest control based on Publication 360, without IPM.
Column E represents the actual total costs of pest control, including the introduction of IPM.
Sources: Table 5 and Appendix Table 24.

For comparison, the total pest control costs in Ontario with and without IPM (columns E and A of Table 7) respectively are illustrated in Figure 6. The area between the upper curve (total potential pest control costs without IPM) and the lower curve (actual total pest control costs with IPM) of Figure 6 is the total benefit to Ontario apple growers - i.e. total cost savings resulting from the investment in IPM on apples. The total cost-savings resulting from the introduction of IPM on apples in Ontario (Table 8) is the measure of benefit that is to be compared to the costs of IPM research and extension.

TABLE 8: Total Cost Savings ($ millions) Resulting from IPM (Pest Control Levels 2 - 4) on Apples in Ontario

Year	Level 2	Level 3-4	Total
1965	0	0	0
1966	0	0	0
1967	0	0	0
1968	0	0	0
1969	0	0	0
1970	1.2	0.04	1.2
1971	1.7	0.06	1.7
1972	1.7	0.06	1.7
1973	1.5	0.05	1.6
1974	1.7	0.05	1.7
1975	2.1	0.11	2.2
1976	2.1	0.20	2.3
1977	2.2	0.26	2.4
1978	3.0	0.41	3.4
1979	4.2	0.60	4.8
1980	6.0	1.09	7.1
1981	5.4	1.66	7.1
1982	5.7	1.86	7.5
1983	4.7	2.06	6.8
1984	4.4	2.47	9.9
Total	47.5	10.99	58.5

It is evident from Table 8 that the total benefit (cost-savings) from IPM during the period 1965 to 1984 is $58.5 million, of which $47.5 million is derived from cost-savings associated with level 2 pest control, and $10.99 million associated with level 3-4 pest control.

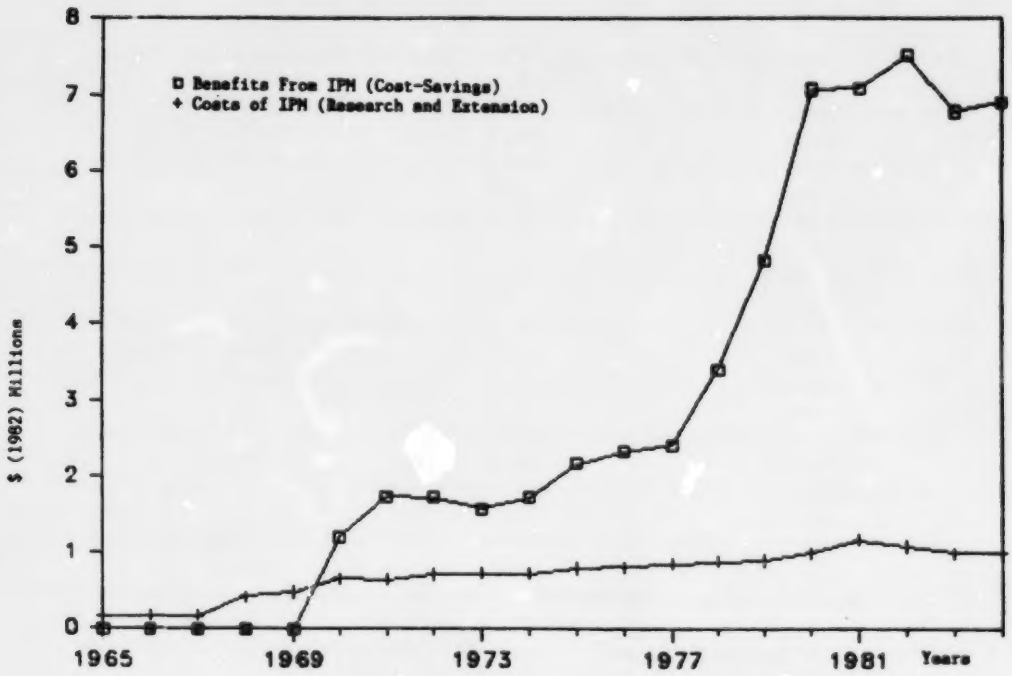
3.2.3 Economic Return to Integrated Pest Management

The final component of this analysis compared the costs and benefits derived from IPM over the time period from 1965 to 1984. The undiscounted benefits and costs (Tables 8 and 4) are illustrated in Table 9 and Figure 7. It is evident that many of the costs associated with the research and development of IPM were incurred prior to 1970, the time when the first benefits of IPM were realized. Annual total research and development costs of IPM gradually increased from $180,000 in 1965 to $1.2 million in 1981, and subsequently declined to $998,000 by 1984. The total investment in IPM research and extension for the entire study period was $14.4 million dollars.

The benefits from IPM, (i.e. reduction in pesticide sprays compared to what may have occurred by following OMAF Publication 360 without IPM), gradually increased from approximately $1.2 million in 1970 to $2.4 million in 1977. The rate of increase in annual benefits grew rapidly to $7.1 million by 1980 and remained relatively constant at approximately $6.8 million until 1984. The total benefits resulting from the introduction of IPM from 1965 to 1984 were $58.5 million.

The ratio of benefits to costs (B/C) ranges from $4.06 to $3.17 return for each dollar invested in IPM on apples, depending upon the discount rate employed (Table 9). The internal rate of return (IRR) of the expenditure ($14.4 million) is 41.56 percent. That is, the total expenditures on pest control levels 2 to 4 returned 41.56% in terms of net benefits (reduction in spray and application costs). This IRR far exceeds "normal" business expectations of 10-20%, thus in comparison to other non-agricultural enterprises, the return to IPM in Ontario apples is well above average.

Figure 7: Comparison Of Benefits and Costs of IPM on Apples in Ontario, 1965-1984



Tabel 9: Economic Return ($ millions) to Investment in Pest Control Levels 2-4 (IPM) on Apples in Ontario

Year	Benefits	Costs	B/C Ratio
1965	0	0.18	
1966	0	0.18	
1967	0	0.18	
1968	0	0.42	
1969	0	0.48	
1970	1.2	0.66	
1971	1.7	0.65	
1972	1.7	0.72	
1973	1.6	0.72	
1974	1.7	0.73	
1975	2.2	0.80	
1976	2.3	0.82	
1977	2.4	0.86	
1978	3.4	0.88	
1979	4.8	0.88	
1980	7.1	0.99	
1981	7.1	1.17	
1982	7.5	1.09	
1983	6.8	0.99	
1984	6.9	1.00	
Total	58.5	14.40	4.06/1
PV (8%)	18.6	5.87	3.17/1
PV (5%)	28.0	8.00	3.59/1
PV (3%)	37.2	10.01	3.72/1

PV = Present Value
B/C = Benefit/Cost
Source: Tables 4 and 8

4. DISCUSSION

In light of the results presented in this study, it is evident that the economic returns to IPM on apples in Ontario far exceed the associated research and extension costs. However, it is important to recognize the limitations of the preceding economic quantification. First, the data used in this analysis (i.e. frequency of pesticide applications by pest control level, research and extension PY, etc.) represent the average or "typical" situation for the Province as a whole. It is known that various apple producing regions will have experienced different returns to IPM. Specifically, the benefit/cost ratio and IRR for each region will be different. Despite this, the Norfolk Fruit Growers Association (Simcoe, Ont.) endorsed the study results as realistic and a fair representation of returns to IPM research, development, and implementation (Appendix A). Further, it was stated that the study results most typified the Haldimand-Norfolk and Niagara regions. It was expected that returns to IPM in the Georgian Bay region would be somewhat greater while the returns in the Essex-Kent region would be less. The computer program developed here can be used to calculate the costs and benefits for any specific set of grower application records.

The results reported herein can only be interpreted in a limited sense. That is, the benefit/cost ratio and IRR measure benefits and costs to the apple producers and funding agencies only. Excluded are all external costs and benefits, such as costs resulting from deleterious environmental impacts when using pesticides, costs to agro-chemical companies resulting from reduced sales of pesticides, benefits to growers and agro-chemical companies from

possible reduction of the development of pesticide resistance, and benefits to growers from reductions in risk of pest infestations. Results from a recent study by the National Research Council (Stemeroff et al., 1985) indicate that the benefits and costs beyond the farm level are greater than those costs and benefits up to the farmgate. This means that in most cases, consumers benefit (or lose) more from pest control actions implemented at the farm-level than farmers themselves. Thus, when interpreting these results it is important to bear in mind that the real benefit/cost ratio and IRR to all of society may be much higher than indicated here.

A final point concerns the benefit/cost and IRR measure themselves. In an absolute sense, (i.e., not compared to other B/C and IRR measures), the B/C ratio and IRR are less useful for policy decision-makers than when presented in comparison to other similar investment projects. Specifically, only limited agricultural research and extension funds are available each year. The allocation of these funds is priorized according to need and expected returns. Thus, when presented with only one set of economic measures (B/C and IRR) for one crop, it is difficult to interpret the "relative" benefit of investing funds in one crop compared to another. For example, a B/C ratio of 4 to 1 from IPM on apples appears very good, but this ratio of dollars returned per one dollar invested can only be judged as "good" or "bad" in comparison to other crops and IPM programs, (e.g. muck crops). Nevertheless, from the economists point of view, any investment which yields a B/C ratio of greater than 1 to 1 is considered economically viable.

REFERENCES

Allan G. E., and J.E. Bath. 1980. The conceptual and institutional aspects of integrated pest management. BioSci. 30:658-664.

Brinkman, G. and B. Prentice. 1981. Agricultural Research-A 40 to 1 return on Investment! Highlights of Agriculture Research in Ontario. June 1981.

Campbell, E.M., 1983. A Study of Canada's Apple Industry. Marketing and Economics Branch, Agriculture Canada, Ottawa.

Flint, M.L. and R. van den Bosch. 1981. Introduction to Integrated Pest Management. Plenum Press, New York. 240 pp.

Hall, D.C. 1977, The profitability of integrated pest management: case studies for cotton and citrus in the San Joaquin Valley. Bull. Entomol. Soc. America 23:267-74.

Huffacker, C.B., C.A. Shoemaker and A.P. Guitierrez. 1978. Current-status urgent needs, and future prospects of integrated pest management. In: Pest Control Strategies. Eds. E.H. Smith and D. Pimental. pp 237-260. Academic Press, New York. 334pp.

Luckmann, W.H. and R.L. Metcalf. 1982. The pest-management concept. In: Introduction to Insect Pest Management. Eds. R.L. Metcalf and W.H. Luckman. pp 1-32. John Wiley and Sons, Toronto. 557 pp.

Ontario Ministry of Agriculture and Food, 1983, 1984a. Agriculture Statistics for Ontario. Publication 20. Statistics Section, Economics Branch.

_____. 1984b. Integrated Pest Management in Ontario. Unpublished inhouse document.

_____. 1985. Fruit Production Recommendations. OMAF Publication 360.

Pfeiffer, W.C., and R. Haack. 1979. An Economic Assessment of Pest Management in Apple Production in Ontario. School of Agricultural Economics and Extension Education. University of Guelph. Guelph, Ontario.

Pickett, A.D. 1949. A critique on insect chemical control methods. Can. Entomol. 81:1-10.

Poston, F.L., L.P. Pedigo and S.M. Welch. 1983. Economic injury levels: Reality and practicality. Bull. Entomol. Soc. Amer. 29:49-53.

Smith, R.F. 1978. History and complexity of Integrated pest management. In: Pest Control Strategies. Eds. E.H. Smith and D. Pimental. pp 41-54. Academic Press, New York. 334 pp.

Stemeroff, M. 1981. The Economics of Pest Monitoring for Onion Production in the Holland and Keswick Marshes of Ontario. Unpublished MSc. thesis, University of Guelph.

Stemeroff, M. and J.A. George. 1983. The Benefits and Costs of Controlling Destructive Insects on Onions, Apples, and Potatoes in Canada, 1960-80. A report prepared for the Entomological Society of Canada. Ottawa. March 1983.

Stemeroff, M., K. Lloyd, R. Roberts. 1985. Evaluation of the Biological and Economic Benefits of Pesticide Use - Strengths and Limitations for Risk/Cost/Benefit Analyses. Submission to the National Research Council, Associate Committee on Scientific Criteria for Environmental Quality. Unpublished. 326 pp.

Statistics Canada. Annual. Cansim Matrices 1393, 5587, and 5588. Statistics Canada, Ottawa.

Tew, B.V., M.E. Wetzstein, J.E. Epperson, and D. Robertson. 1982. Economics of Selected Integrated Pest Management Production Systems in Georgia. University of Georgia. Research Report No. 395.

Thompson, M.S., 1983. Benefit-Cost Analysis for Program Evaluation. Sage Publications, Beverly Hills, USA. 310 pp.

Treasury Board of Canada. 1976. Benefit-Cost Analysis Guide. Planning Branch, Treasury Board Secretariate, March 1976. 80 pp.

PERSONAL COMMUNICATIONS

Collver, K. 1985 - Norfolk Fruit Growers Association. Simcoe, Ontario.

Ells, B. 1984 - Plant Industry Branch, OMAF, Bowmansville, Ontario.

Hagley, E. 1984 - Research Branch, Agriculture Canada, Vineland Research Station, Vineland, Ontario.

Hunter, C. 1984 - Plant Industry Branch, OMAF, Horticultural Research Institute of Ontario, Simcoe, Ontario.

Roberts, W. 1984 - Plant Industry Branch, OMAF, Guelph, Ontario.

APPENDIX A

THE NORFOLK FRUIT GROWERS' ASSOCIATION

TELEPHONE (519) 426-0640

QUEENSWAY AVE., EAST, P.O. BOX 296
CABLE "NORFOLK"

SIMCOE, ONTARIO
N3Y 4L1

February 14, 1985

Culice & Stemeroff & Associates Ltd.
380 Woolwich Street
GUELPH, Ontario
N1H 3W7

Attn: Messrs. D.J. Madder
Marvin Stemeroff

Dear Sirs:

This is to acknowledge receipt of your interim results of the study you have presently undertaken with reference to integrated pest management on behalf of the Government of Ontario.

The meeting between yourselves and producer members of this Association indicated very clearly that your findings, from across Ontario, correspond very closely to those of actual practice by the apple producers in this area. It is obvious, there are some regional differences pertaining to the types of materials used and relative to the incidence of insects and disease relative to varieties grown in various areas of the province. To date, your studies show very clearly that integrated pest management has reduced dramatically the incidence of pesticide applications relative to the production of apples.

We would be most interested in receiving a copy of the finalized report and thank you for giving us the opportunity for input to your study.

Yours very truly,
THE NORFOLK FRUIT GROWERS' ASSOCIATION

KC:jb

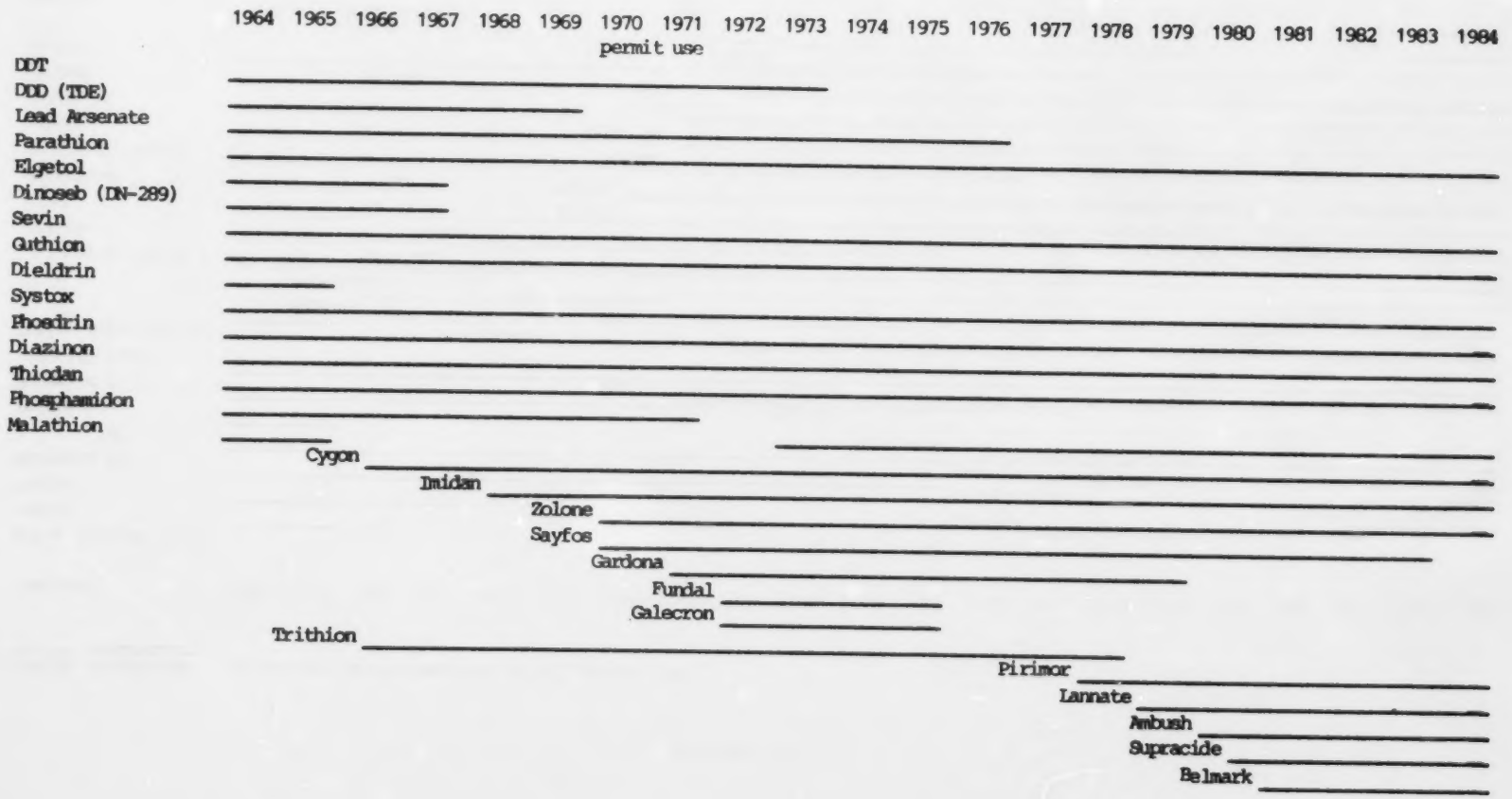
Keith R. Collver, P.Ag.
General Manager

APPENDIX TABLES

Sources for Appendix Tables 1 - 3: W. Roberts, Plant Industry Branch, OMAF, Guelph, Ontario

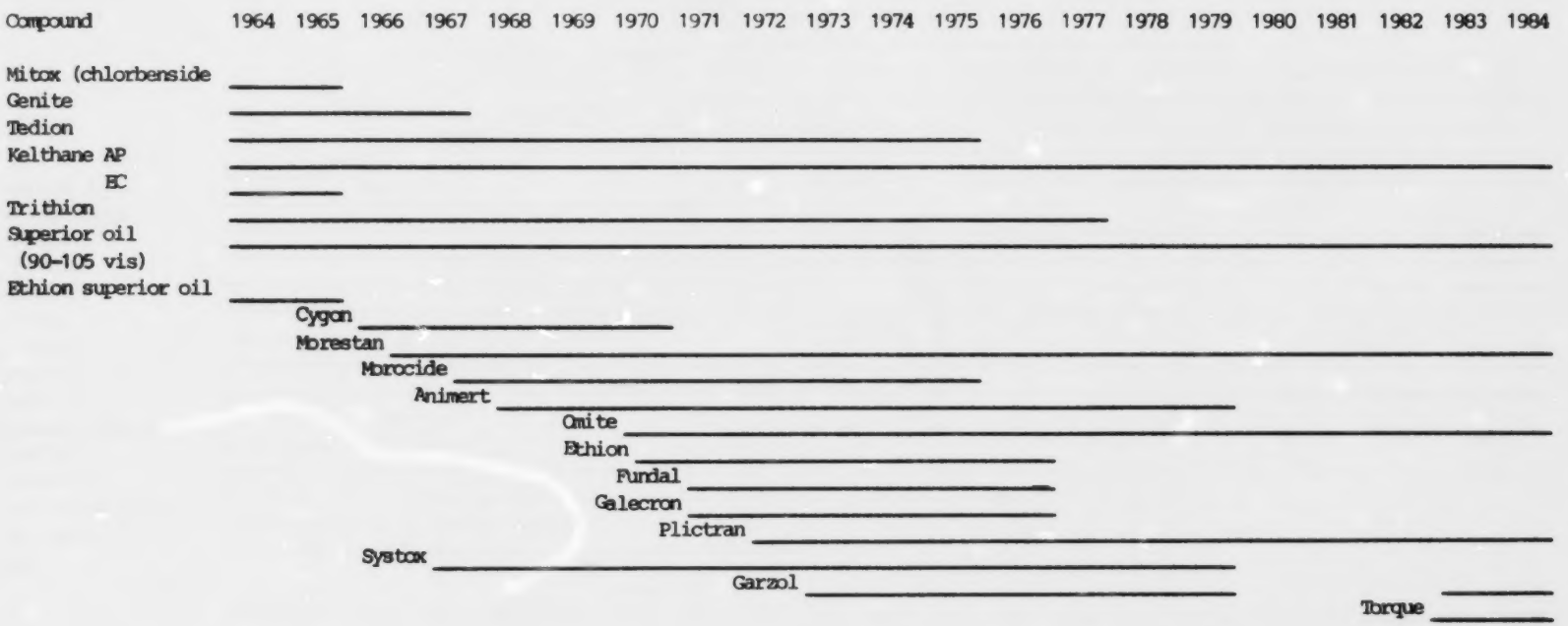
Appendix Table 1

APPLES: INSECTICIDES Registered and Recommended in Publication 360



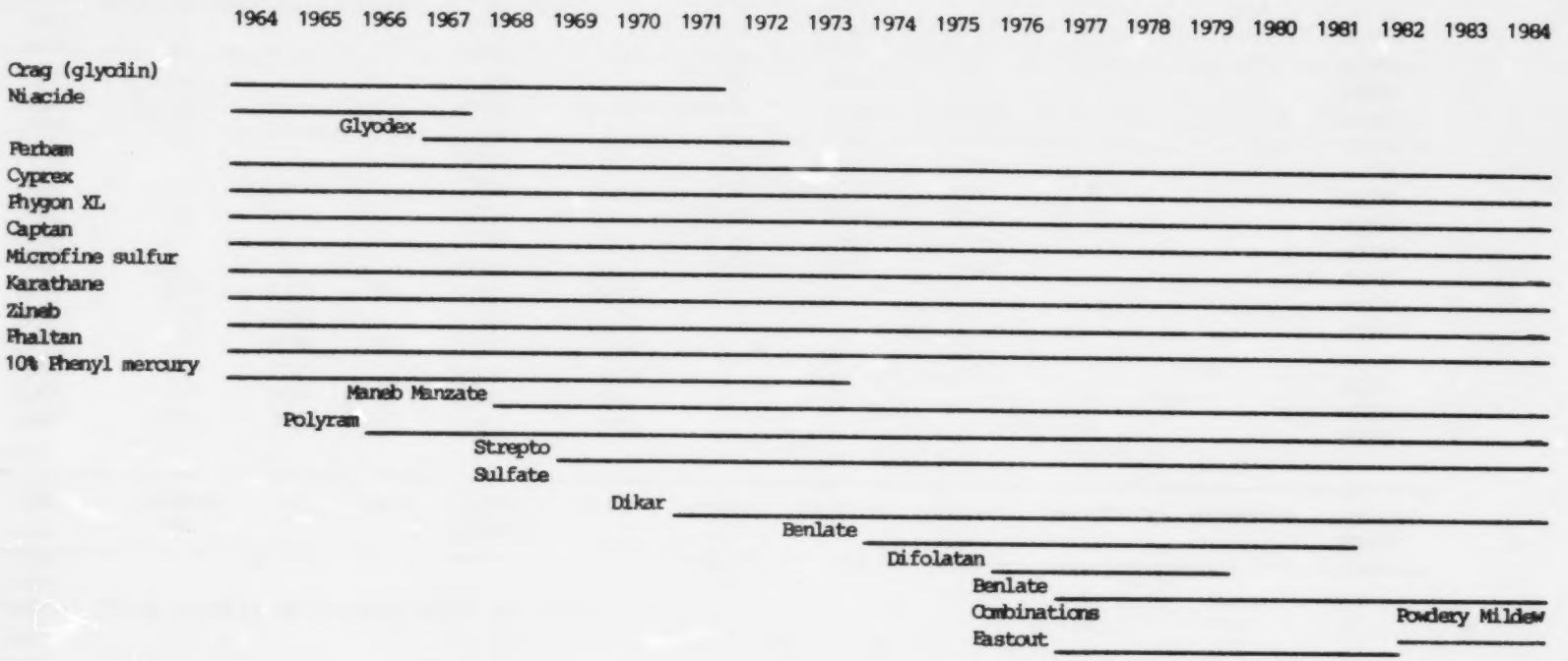
Appendix Table 2

APPLES: Acaricides Registered and Recommended in Publication 360



Appendix Table 3

APPLES: FUNGICIDES Registered and Recommended in Publication 360



Sources for Appendix Tables 4-12: W. Roberts, OMAF, Guelph; B. Ells, OMAF, Bowmanville; E. Hagley, Agriculture Canada, Vineland; C. Hunter, Plant Industry Branch, OMAF, Simcoe, Ontario; Norfolk Fruit Growers Association; Georgian Bay spray records.

Appendix Table 4

LEVEL 1: ANNUAL APPLICATIONS OF INSECTICIDES IN ONTARIO

YEAR	LEAD ARSENATE	DDT	DDD	azinphos-methyl	carbaryl	phosmet	phosalone	diazinon	fenvalerate	permethrin	Annual Frequency
1965	2.00	3.00		1.00	2.00						8.00
1966	2.00	3.00	1.00	1.00	2.00						9.00
1967	2.00	3.00		1.00	2.00						8.00
1968	2.00	3.00	1.00	1.00	2.00						9.00
1969	2.00	3.00		1.00	2.00						8.00
1970	2.00	2.00	1.00	1.00	2.00						8.00
1971				4.00		2.00	2.00	2.00			10.00
1972				4.00		2.00	2.00	2.00			10.00
1973				4.00		2.00	2.00	2.00			10.00
1974				2.00		3.00	3.00	2.00			10.00
1975				2.00		3.00	3.00	2.00			10.00
1976				3.00		2.50	2.50	2.00			10.00
1977				4.00		2.00	2.00	2.00			10.00
1978				3.00		2.50	2.50	2.00			10.00
1979				2.00		2.00	2.00	2.00	1.00	1.00	10.00
1980				2.00		2.00	2.00	2.00	1.00	1.00	10.00
1981				2.00		3.00	2.00	1.00	1.00	1.00	10.00
1982				2.00		2.50	2.00	1.50	1.00	1.00	10.00
1983				2.00		2.50	2.00	1.50	1.00	1.00	10.00
1984				2.00		2.50	2.00	1.50	1.00	1.00	10.00

Appendix Table 5

LEVEL 2: ANNUAL APPLICATIONS OF INSECTICIDES IN ONTARIO

YEAR	LEAD ARSENATE	DDT	DDD	azinphos-methyl	carbaryl	phosmet	phosalone	diazinon	fenvalerate	permethrin	Annual Frequency
1965	2.0	3.0		1.0	2.0						8.0
1966	2.0	3.0	1.0	1.0	2.0						9.0
1967	2.0	3.0		1.0	2.0						8.0
1968	2.0	3.0	1.0	1.0	2.0						9.0
1969	2.0	3.0		1.0	2.0						8.0
1970	2.0	2.0	1.0	1.0	2.0						8.0
1971				2.0		1.0	1.0	1.0			5.0
1972				2.0		1.0	1.0	1.0			5.0
1973				2.0		1.0	1.0	1.0			5.0
1974				1.0		1.5	1.5	1.0			5.0
1975				1.0		1.5	1.5	1.0			5.0
1976				2.0		1.5	1.5	1.0			6.0
1977				2.0		1.0	1.0	1.0			5.0
1978				2.0		1.5	1.5	1.0			6.0
1979				1.0		1.0	1.0	1.0	0.5	0.5	5.0
1980				1.0		1.5	1.5	1.0	0.5	0.5	6.0
1981				1.0		1.5	1.0	0.5	0.5	0.5	5.0
1982				1.0		2.0	1.0	1.0	0.5	0.5	6.0
1983				1.0		2.0	1.0	1.0	0.5	0.5	6.0
1984				1.0		2.0	1.0	1.0	0.5	0.5	6.0

Appendix Table 6

LEVEL 3: ANNUAL APPLICATIONS OF INSECTICIDES IN ONTARIO

YEAR	LEAD ARSENATE	DDT	DDD	azinphos-methyl	carbaryl	phosmet	phosalone	diazinon	fenvalerate	permethrin	Annual Frequency
1965	2.00	3.00		1.00	2.00						8.00
1966	2.00	3.00	1.00	1.00	2.00						9.00
1967	2.00	3.00		1.00	2.00						8.00
1968	2.00	3.00	1.00	1.00	2.00						9.00
1969	2.00	3.00		1.00	2.00						8.00
1970	2.00	2.00	1.00	1.00	2.00						8.00
1971				2.00		1.00	1.00	1.00			5.00
1972				2.00		1.00	1.00	1.00			5.00
1973				2.00		1.00	1.00	1.00			5.00
1974				1.00		1.50	1.50	1.00			5.00
1975				1.00		1.50	1.50	1.00			5.00
1976				1.50		1.25	1.25	1.00			5.00
1977				2.00		1.00	1.00	1.00			5.00
1978				1.50		1.25	1.25	1.00			5.00
1979				1.00		1.00	1.00	1.00	0.50	0.50	5.00
1980				0.75		1.25	1.25	0.75	0.50	0.50	5.00
1981				1.00		1.50	1.00	0.50	0.50	0.50	5.00
1982				1.00		1.50	0.75	0.75	0.50	0.50	5.00
1983				1.00		1.50	0.75	0.75	0.50	0.50	5.00
1984				1.00		1.50	0.75	0.75	0.50	0.50	5.00

Appendix Table 7

LEVEL 1: ANNUAL APPLICATIONS OF ACARICIDES ON APPLES IN ONTARIO

YEAR	Superior Oil	dicofol	demeton	tetra-difon	binapa-cryl	chlordim-eform	Plictran	oxythio-quinox	formetanate hydrochloride	Total Frequency
1965		1.00		1.00	1.00					3.00
1966	1.00	1.00		0.50	0.50					3.00
1967		1.00	1.00	0.50	0.50					3.00
1968	1.00	1.00	1.00							3.00
1969		1.00	1.00	0.50	0.50					3.00
1970	1.00					2.00				3.00
1971						3.00				3.00
1972	1.00					2.00				3.00
1973						1.50	1.50			3.00
1974	1.00					1.00	1.00			3.00
1975						1.00	2.00			3.00
1976						1.00	2.00			3.00
1977			1.00				2.00			3.00
1978		1.00					2.00			3.00
1979		1.50					2.00			3.50
1980		1.50					2.50			4.00
1981	0.50	1.00					2.00	0.50		4.00
1982	0.50	1.00					2.00	0.50		4.00
1983	0.90	1.25					1.25	0.30	0.30	4.00
1984	0.90	1.25					1.25	0.30	0.30	4.00

Appendix Table 8

LEVEL 2: ANNUAL APPLICATIONS OF ACARICIDES ON APPLES IN ONTARIO

YEAR	Superior Oil	dicofol	demeton	tetra-difon	binapa-cryl	chlordim-eform	Plictran	oxythio-quinox	formetanate hydrochloride	Total Frequency
1965		1.00		1.00	1.00					3.00
1966	1.00	1.00		0.50	0.50					3.00
1967		1.00	1.00	0.50	0.50					3.00
1968	1.00	1.00	1.00							3.00
1969		1.00	1.00	0.50	0.50					3.00
1970	1.00					1.00				2.00
1971						2.00				2.00
1972	1.00					1.00				2.00
1973						1.00	1.00			2.00
1974	1.00					0.50				1.50
1975						0.50	1.00			1.50
1976						0.50	1.00			1.50
1977			0.50				1.00			1.50
1978		0.50					1.00			1.50
1979		0.50					1.00			1.50
1980							1.00			1.00
1981	0.50	0.50					1.00	0.25		2.25
1982	0.50	0.50					1.00	0.50		2.50
1983	0.50	1.00					1.00	0.25	0.25	3.00
1984	0.50	1.00					1.00	0.25	0.50	3.25

Appendix Table 9

LEVEL 3-4: ANNUAL APPLICATIONS OF ACARICIDES ON APPLES IN ONTARIO

YEAR	Superior Oil	dicofol	demeton	tetra-difon	binapa-cryl	chlordim-eform	Plictran	oxythio-quinox	formetanate hydrochloride	Total Frequency
1965		1.00		1.00	1.00					3.00
1966	1.00	1.00		0.50	0.50					3.00
1967		1.00	1.00	0.50	0.50					3.00
1968	1.00	1.00	1.00							3.00
1969		1.00	1.00	0.50	0.50					3.00
1970	1.00					0.50				1.50
1971						1.25				1.25
1972	0.50					0.50				1.00
1973						0.50	0.50			1.00
1974	0.50					0.50				1.00
1975						0.25	0.75			1.00
1976						0.25	0.75			1.00
1977			0.25				0.75			1.00
1978		0.25					0.75			1.00
1979		0.25					0.75			1.00
1980							1.00			1.00
1981	0.25	0.25					0.75	0.25		1.50
1982	0.50	0.25					0.75	0.25		1.75
1983	0.25	0.50					0.75	0.25	0.25	2.00
1984	0.25	0.50					0.75	0.25	0.25	2.00

Appendix Table 10

LEVEL 1: ANNUAL APPLICATIONS OF FUNGICIDES ON APPLES IN ONTARIO

YEAR	dodine	dichlone	captan	microfine sulfur	phenyl mercury (10%)	polyram	dikar	benomyl	other	Annual Frequency
1965	4.20	0.25	5.75	1.40	1.40				0.50	13.50
1966	3.50	0.25	5.50	0.75	1.20	2.00			0.25	13.45
1967	3.60	0.25	5.45		1.20	2.50			0.25	13.25
1968	4.25	0.25	5.00		1.00	2.50			0.25	13.25
1969	4.25	0.25	5.00		1.00	2.25			0.25	13.00
1970	4.25	0.25	4.50		1.00	2.75			0.25	13.00
1971	5.25	0.25	4.25			3.00			0.25	13.00
1972	4.75	0.25	4.25			3.50			0.25	13.00
1973	3.50	0.25	4.25			4.75			0.25	13.00
1974	2.10	0.25	3.70			4.50	1.00	1.20	0.25	13.00
1975	1.50	0.25	4.50			4.00	1.00	1.50	0.25	13.00
1976	1.25	0.25	5.25			4.00	1.00	1.00	0.25	13.00
1977		0.25	5.25			4.00	2.00	1.25	0.25	13.00
1978		0.25	5.25			5.25	2.00		0.25	13.00
1979		0.25	5.25			5.00	2.25		0.25	13.00
1980		0.25	4.75			4.50	3.25		0.25	13.00
1981	0.50	0.25	4.50			4.00	3.50		0.25	13.00
1982	0.50	0.25	4.50			4.00	3.50		0.25	13.00
1983	0.50	0.25	4.50			4.00	3.50		0.25	13.00
1984	0.50	0.25	4.50			4.00	3.50		0.25	13.00

Other = any one, or combination of the following:
zineb, maneb, thiophanatemethyl

Appendix Table 11

LEVEL 2: ANNUAL APPLICATIONS OF FUNGICIDES ON APPLES IN ONTARIO

YEAR	dodine	dichlone	captan	microfine sulfur	phenyl mercury (10%)	polyram	dikar	benomyl	other	Annual Frequency
1965	4.20	0.25	5.75	1.40	1.40				0.50	13.50
1966	3.50	0.25	5.50	0.75	1.20	2.00			0.25	13.45
1967	3.60	0.25	5.45		1.20	2.50			0.25	13.25
1968	4.25	0.25	5.00		1.00	2.50			0.25	13.25
1969	4.25	0.25	5.00		1.00	2.25			0.25	13.00
1970	2.50	0.15	4.25		0.50	2.45			0.15	10.00
1971	3.00	0.15	4.25			2.50			0.10	10.00
1972	3.00	0.15	4.25			2.50			0.10	10.00
1973	2.75	0.15	4.00			3.00			0.10	10.00
1974	1.00	0.15	4.00			3.00	0.75	1.00	0.10	10.00
1975	1.00	0.15	4.00			3.00	0.75	1.00	0.10	10.00
1976	0.50	0.15	4.00			3.25	1.00	1.00	0.10	10.00
1977		0.15	4.00			3.50	1.50	0.75	0.10	10.00
1978		0.15	4.25			4.00	1.50		0.10	10.00
1979		0.15	4.25			4.00	1.50		0.10	10.00
1980		0.15	4.00			3.75	2.00		0.10	10.00
1981	0.25	0.15	3.75			3.75	2.00		0.10	10.00
1982	0.25	0.15	3.75			3.75	2.00		0.10	10.00
1983	0.25	0.15	3.75			3.75	2.00		0.10	10.00
1984	0.25	0.15	3.75			3.75	2.00		0.10	10.00

Other = any one, or combination of the following:
zineb, maneb, thiophanatemethyl

Appendix Table 12

LEVELS 3-4: ANNUAL APPLICATIONS OF FUNGICIDES ON APPLES IN ONTARIO

YEAR	dodine	dichlone	captan	microfine sulfur	phenyl mercury (10%)	polyram	dikar	benomyl	other	Annual Frequency
1965	4.20	0.25	5.75	1.40	1.40				0.50	13.50
1966	3.50	0.25	5.50	0.75	1.20	2.00			0.25	13.45
1967	3.60	0.25	5.45		1.20	2.50			0.25	13.25
1968	4.25	0.25	5.00		1.00	2.50			0.25	13.25
1969	4.25	0.25	5.00		1.00	2.25			0.25	13.00
1970	2.50	0.15	4.25		0.50	2.45			0.15	10.00
1971	3.00	0.15	4.25			2.50			0.10	10.00
1972	3.00	0.15	4.25			2.50			0.10	10.00
1973	2.75	0.15	4.00			3.00			0.10	10.00
1974	1.00	0.15	4.00			3.00	0.75	1.00	0.10	10.00
1975	0.75	0.10	3.85			2.85	0.60	0.75	0.10	9.00
1976	0.25	0.10	4.00			2.80	1.00	0.75	0.10	9.00
1977		0.10	3.75			3.25	1.25	0.55	0.10	9.00
1978		0.10	3.80			3.50	1.50		0.10	9.00
1979		0.10	3.80			3.50	1.50		0.10	9.00
1980		0.10	3.70			3.50	1.60		0.10	9.00
1981	0.10	0.10	3.50			3.50	1.70		0.10	9.00
1982	0.10	0.10	3.50			3.50	1.70		0.10	9.00
1983	0.10	0.10	3.50			3.50	1.70		0.10	9.00
1984	0.10	0.10	3.50			3.50	1.70		0.10	9.00

Other = any one, or combination of the following:
zineb, maneb, thiophanatemethyl

Appendix Table 13

LEVEL 1: ANNUAL COSTS OF INSECTICIDES ON APPLES IN ONTARIO ($/HA)

YEAR	LEAD ARSENATE	DDT	DDD	azinphos-methyl	carbaryl	phosmet	phosalone	diazinon	fenvalerate	permethrin	Annual Cost
1965	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1966	64.00	87.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	286.97
1967	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1968	64.00	87.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	286.97
1969	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1970	64.00	58.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	257.97
1971	0.00	0.00	0.00	128.68	0.00	64.26	51.02	82.22	0.00	0.00	326.18
1972	0.00	0.00	0.00	128.68	0.00	64.26	51.02	82.22	0.00	0.00	326.18
1973	0.00	0.00	0.00	128.68	0.00	64.26	51.02	82.22	0.00	0.00	326.18
1974	0.00	0.00	0.00	64.34	0.00	96.39	76.53	82.22	0.00	0.00	319.48
1975	0.00	0.00	0.00	64.34	0.00	96.39	76.53	82.22	0.00	0.00	319.48
1976	0.00	0.00	0.00	96.51	0.00	80.33	63.78	82.22	0.00	0.00	322.83
1977	0.00	0.00	0.00	128.68	0.00	64.26	51.02	82.22	0.00	0.00	326.18
1978	0.00	0.00	0.00	96.51	0.00	80.33	63.78	82.22	0.00	0.00	322.83
1979	0.00	0.00	0.00	64.34	0.00	64.26	51.02	82.22	37.87	33.66	333.37
1980	0.00	0.00	0.00	64.34	0.00	64.26	51.02	82.22	37.87	33.66	333.37
1981	0.00	0.00	0.00	64.34	0.00	96.39	51.02	41.11	37.87	33.66	324.39
1982	0.00	0.00	0.00	64.34	0.00	80.33	51.02	61.67	37.87	33.66	328.88
1983	0.00	0.00	0.00	64.34	0.00	80.33	51.02	61.67	37.87	33.66	328.88
1984	0.00	0.00	0.00	64.34	0.00	80.33	51.02	61.67	37.87	33.66	328.88

Appendix Table 14

LEVEL 2: ANNUAL COSTS OF INSECTICIDES ON APPLES IN ONTARIO ($/HA)

YEAR	LEAD ARSENATE	DDT	DDD	azinphos-methyl	carbaryl	phosmet	phosalone	diazinon	fenvalerate	permethrin	Annual Cost
1965	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1966	64.00	87.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	286.97
1967	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1968	64.00	87.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	286.97
1969	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1970	64.00	58.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	257.97
1971	0.00	0.00	0.00	64.34	0.00	32.13	25.51	41.11	0.00	0.00	163.09
1972	0.00	0.00	0.00	64.34	0.00	32.13	25.51	41.11	0.00	0.00	163.09
1973	0.00	0.00	0.00	64.34	0.00	32.13	25.51	41.11	0.00	0.00	163.09
1974	0.00	0.00	0.00	32.17	0.00	48.20	38.27	41.11	0.00	0.00	159.74
1975	0.00	0.00	0.00	32.17	0.00	48.20	38.27	41.11	0.00	0.00	159.74
1976	0.00	0.00	0.00	64.34	0.00	48.20	38.27	41.11	0.00	0.00	191.91
1977	0.00	0.00	0.00	64.34	0.00	32.13	25.51	41.11	0.00	0.00	163.09
1978	0.00	0.00	0.00	64.34	0.00	48.20	38.27	41.11	0.00	0.00	191.91
1979	0.00	0.00	0.00	32.17	0.00	32.13	25.51	41.11	18.94	16.83	166.69
1980	0.00	0.00	0.00	32.17	0.00	48.20	38.27	41.11	18.94	16.83	195.51
1981	0.00	0.00	0.00	32.17	0.00	48.20	25.51	20.56	18.94	16.83	162.20
1982	0.00	0.00	0.00	32.17	0.00	64.26	25.51	41.11	18.94	16.83	198.82
1983	0.00	0.00	0.00	32.17	0.00	64.26	25.51	41.11	18.94	16.83	198.82
1984	0.00	0.00	0.00	32.17	0.00	64.26	25.51	41.11	18.94	16.83	198.82

Appendix Table 15

LEVELS 3-4: ANNUAL COSTS OF INSECTICIDES ON APPLES IN ONTARIO ($/HA)

YEAR	LEAD ARSENATE	DDT	DDD	azinphos-methyl	carbaryl	phosmet	phosalone	diazinon	fenvalerate	permethrin	Annual Cost
1965	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1966	64.00	87.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	286.97
1967	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1968	64.00	87.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	286.97
1969	64.00	87.00	0.00	32.17	52.00	0.00	0.00	0.00	0.00	0.00	235.17
1970	64.00	58.00	51.80	32.17	52.00	0.00	0.00	0.00	0.00	0.00	257.97
1971	0.00	0.00	0.00	64.34	0.00	32.13	25.51	41.11	0.00	0.00	163.09
1972	0.00	0.00	0.00	64.34	0.00	32.13	25.51	41.11	0.00	0.00	163.09
1973	0.00	0.00	0.00	64.34	0.00	32.13	25.51	41.11	0.00	0.00	163.09
1974	0.00	0.00	0.00	32.17	0.00	48.20	38.27	41.11	0.00	0.00	159.74
1975	0.00	0.00	0.00	32.17	0.00	48.20	38.27	41.11	0.00	0.00	159.74
1976	0.00	0.00	0.00	48.26	0.00	40.16	31.89	41.11	0.00	0.00	161.42
1977	0.00	0.00	0.00	64.34	0.00	32.13	25.51	41.11	0.00	0.00	163.09
1978	0.00	0.00	0.00	43.26	0.00	40.16	31.89	41.11	0.00	0.00	161.42
1979	0.00	0.00	0.00	32.17	0.00	32.13	25.51	41.11	18.94	16.83	166.69
1980	0.00	0.00	0.00	24.13	0.00	40.16	31.89	30.83	18.94	16.83	162.78
1981	0.00	0.00	0.00	32.17	0.00	48.20	25.51	20.56	18.94	16.83	162.20
1982	0.00	0.00	0.00	32.17	0.00	48.20	19.13	30.83	18.94	16.83	166.10
1983	0.00	0.00	0.00	32.17	0.00	48.20	19.13	30.83	18.94	16.83	166.10
1984	0.00	0.00	0.00	32.17	0.00	48.20	19.13	30.83	18.94	16.83	166.10

Appendix Table 16

LEVEL 1: ANNUAL COSTS OF ACARICIDES ON APPLES IN ONTARIO ($/Ha)

YEAR	Superior Oil	dicofol	demeton	tetra-difon	binapa-cryl	chlordim-eform	Plictran	oxythio-quinox	formetanate hydrochloride	Annual Costs
1965	0.00	75.38	0.00	16.67	20.03	0.00	0.00	0.00	0.00	112.08
1966	27.71	75.38	0.00	8.34	10.02	0.00	0.00	0.00	0.00	121.44
1967	0.00	75.38	35.36	8.34	10.02	0.00	0.00	0.00	0.00	129.09
1968	27.71	75.38	35.36	0.00	0.00	0.00	0.00	0.00	0.00	138.45
1969	0.00	75.38	35.36	8.34	10.02	0.00	0.00	0.00	0.00	129.09
1970	27.71	0.00	0.00	0.00	0.00	281.98	0.00	0.00	0.00	309.69
1971	0.00	0.00	0.00	0.00	0.00	422.97	0.00	0.00	0.00	422.97
1972	27.71	0.00	0.00	0.00	0.00	281.98	0.00	0.00	0.00	309.69
1973	0.00	0.00	0.00	0.00	0.00	211.49	97.58	0.00	0.00	309.06
1974	27.71	0.00	0.00	0.00	0.00	140.99	65.05	0.00	0.00	233.75
1975	0.00	0.00	0.00	0.00	0.00	140.99	130.10	0.00	0.00	271.09
1976	0.00	0.00	0.00	0.00	0.00	140.99	130.10	0.00	0.00	271.09
1977	0.00	0.00	35.36	0.00	0.00	0.00	130.10	0.00	0.00	165.46
1978	0.00	75.38	0.00	0.00	0.00	0.00	130.10	0.00	0.00	205.48
1979	0.00	113.07	0.00	0.00	0.00	0.00	130.10	0.00	0.00	243.17
1980	0.00	113.07	0.00	0.00	0.00	0.00	162.63	0.00	0.00	275.70
1981	13.86	75.38	0.00	0.00	0.00	0.00	130.10	27.57	0.00	246.90
1982	13.86	75.38	0.00	0.00	0.00	0.00	130.10	27.57	0.00	246.90
1983	24.94	94.23	0.00	0.00	0.00	0.00	81.31	16.54	22.39	239.41
1984	24.94	94.23	0.00	0.00	0.00	0.00	81.31	16.54	22.39	239.41

Appendix Table 17

LEVEL 2: ANNUAL COSTS OF ACARICIDES ON APPLES IN ONTARIO ($/Ha)

YEAR	Superior Oil	dicofol	demeton	tetra-difon	binapa-cryl	chlordim-eform	Plictran	oxythio-quinox	formetanate hydrochloride	Annual Costs
1965	0.00	75.38	0.00	16.67	20.03	0.00	0.00	0.00	0.00	112.08
1966	27.71	75.38	0.00	8.34	10.02	0.00	0.00	0.00	0.00	121.44
1967	0.00	75.38	35.36	8.34	10.02	0.00	0.00	0.00	0.00	129.09
1968	27.71	75.38	35.36	0.00	0.00	0.00	0.00	0.00	0.00	138.45
1969	0.00	75.38	35.36	8.34	10.02	0.00	0.00	0.00	0.00	129.09
1970	27.71	0.00	0.00	0.00	0.00	140.99	0.00	0.00	0.00	168.70
1971	0.00	0.00	0.00	0.00	0.00	281.98	0.00	0.00	0.00	281.98
1972	27.71	0.00	0.00	0.00	0.00	140.99	0.00	0.00	0.00	168.70
1973	0.00	0.00	0.00	0.00	0.00	140.99	65.05	0.00	0.00	206.04
1974	27.71	0.00	0.00	0.00	0.00	70.50	0.00	0.00	0.00	98.21
1975	0.00	0.00	0.00	0.00	0.00	70.50	65.05	0.00	0.00	135.55
1976	0.00	0.00	0.00	0.00	0.00	70.50	65.05	0.00	0.00	135.55
1977	0.00	0.00	17.68	0.00	0.00	0.00	65.05	0.00	0.00	82.73
1978	0.00	37.69	0.00	0.00	0.00	0.00	65.05	0.00	0.00	102.74
1979	0.00	37.69	0.00	0.00	0.00	0.00	65.05	0.00	0.00	102.74
1980	0.00	0.00	0.00	0.00	0.00	0.00	65.05	0.00	0.00	65.05
1981	13.86	37.69	0.00	0.00	0.00	0.00	65.05	13.78	0.00	130.38
1982	13.86	37.69	0.00	0.00	0.00	0.00	65.05	27.57	0.00	144.16
1983	13.86	75.38	0.00	0.00	0.00	0.00	65.05	13.78	18.66	186.73
1984	13.86	75.38	0.00	0.00	0.00	0.00	65.05	13.78	37.32	205.39

Appendix Table 18

LEVELS 3-4: ANNUAL COSTS OF ACARICIDES ON APPLES IN ONTARIO ($/Ha)

YEAR	Superior Oil	dicofol	demeton	tetra-difon	binapa-cryl	chlordim-eform	Plictran	oxythio-quinox	formetanate hydrochloride	Annual Costs
1965	0.00	75.38	0.00	16.67	20.03	0.00	0.00	0.00	0.00	112.08
1966	27.71	75.38	0.00	8.34	10.02	0.00	0.00	0.00	0.00	121.44
1967	0.00	75.38	35.36	8.34	10.02	0.00	0.00	0.00	0.00	129.09
1968	27.71	75.38	35.36	0.00	0.00	0.00	0.00	0.00	0.00	138.45
1969	0.00	75.38	35.36	8.34	10.02	0.00	0.00	0.00	0.00	129.09
1970	27.71	0.00	0.00	0.00	0.00	70.50	0.00	0.00	0.00	98.21
1971	0.00	0.00	0.00	0.00	0.00	176.24	0.00	0.00	0.00	176.24
1972	13.86	0.00	0.00	0.00	0.00	70.50	0.00	0.00	0.00	84.35
1973	0.00	0.00	0.00	0.00	0.00	70.50	32.53	0.00	0.00	103.02
1974	13.86	0.00	0.00	0.00	0.00	70.50	0.00	0.00	0.00	84.35
1975	0.00	0.00	0.00	0.00	0.00	35.25	48.79	0.00	0.00	84.04
1976	0.00	0.00	0.00	0.00	0.00	35.25	48.79	0.00	0.00	84.04
1977	0.00	0.00	8.84	0.00	0.00	0.00	48.79	0.00	0.00	57.63
1978	0.00	18.85	0.00	0.00	0.00	0.00	48.79	0.00	0.00	67.63
1979	0.00	18.85	0.00	0.00	0.00	0.00	48.79	0.00	0.00	67.63
1980	0.00	0.00	0.00	0.00	0.00	0.00	65.05	0.00	0.00	65.05
1981	6.93	18.85	0.00	0.00	0.00	0.00	48.79	13.78	0.00	88.34
1982	13.86	18.85	0.00	0.00	0.00	0.00	48.79	13.78	0.00	95.27
1983	6.93	37.69	0.00	0.00	0.00	0.00	48.79	13.78	18.66	125.85
1984	6.93	37.69	0.00	0.00	0.00	0.00	48.79	13.78	18.66	125.85

Appendix Table 19

LEVEL 1: ANNUAL COSTS OF FUNGICIDES ON APPLES IN ONTARIO ($/Ha)

YEAR	dodine	dichlone	captan	microfine sulfur	phenyl mercury	polyram	dikar	benomyl	other	Annual Costs
1965	207.90	8.37	213.50	14.59	23.84	0.00	0.00	0.00	18.00	$486.19
1966	173.25	8.37	204.50	7.82	20.44	77.90	0.00	0.00	9.00	$500.98
1967	178.20	8.37	202.36	0.00	20.44	97.38	0.00	0.00	9.00	$515.73
1968	210.38	8.37	185.65	0.00	17.03	97.38	0.00	0.00	9.00	$527.80
1969	210.38	8.37	185.65	0.00	17.03	87.64	0.00	0.00	9.00	$518.06
1970	210.38	8.37	167.09	0.00	17.03	107.11	0.00	0.00	9.00	$518.57
1971	259.88	8.37	157.80	0.00	0.00	116.85	0.00	0.00	9.00	$551.89
1972	235.13	8.37	157.80	0.00	0.00	136.33	0.00	0.00	9.00	$546.62
1973	173.25	8.37	157.80	0.00	0.00	185.01	0.00	0.00	9.00	$533.43
1974	103.95	8.37	137.38	0.00	0.00	175.28	53.34	29.20	9.00	$516.51
1975	74.25	8.37	167.09	0.00	0.00	155.80	53.34	36.50	9.00	$504.34
1976	61.88	8.37	194.93	0.00	0.00	155.80	53.34	24.33	9.00	$507.64
1977	0.00	8.37	194.93	0.00	0.00	155.80	106.68	30.41	9.00	$505.19
1978	0.00	8.37	194.93	0.00	0.00	204.49	106.68	0.00	9.00	$523.47
1979	0.00	8.37	194.93	0.00	0.00	194.75	120.02	0.00	9.00	$527.06
1980	0.00	8.37	176.37	0.00	0.00	175.28	173.36	0.00	9.00	$542.36
1981	24.75	8.37	167.09	0.00	0.00	155.80	186.69	0.00	9.00	$551.69
1982	24.75	8.37	167.09	0.00	0.00	155.80	186.69	0.00	9.00	$551.69
1983	24.75	8.37	167.09	0.00	0.00	155.80	186.69	0.00	9.00	$551.69
1984	24.75	8.37	167.09	0.00	0.00	155.80	186.69	0.00	9.00	$551.69

Appendix Table 20

LEVEL 2: ANNUAL COSTS OF FUNGICIDES ON APPLES IN ONTARIO ($/Ha)

YEAR	dodine	dichlone	captan	microfine sulfur	phenyl mercury	polyram	dikar	benomyl	other	Annual Costs
1965	207.90	8.37	213.50	14.59	23.84	0.00	0.00	0.00	18.00	$486.19
1966	173.25	8.37	204.22	7.82	20.44	77.90	0.00	0.00	9.00	$500.98
1967	178.20	8.37	202.36	0.00	20.44	97.38	0.00	0.00	9.00	$515.73
1968	210.38	8.37	185.65	0.00	17.03	97.38	0.00	0.00	9.00	$527.80
1969	210.38	8.37	185.65	0.00	17.03	87.64	0.00	0.00	9.00	$518.06
1970	123.75	5.02	157.80	0.00	8.52	95.43	0.00	0.00	5.40	$395.91
1971	148.50	5.02	157.80	0.00	0.00	97.38	0.00	0.00	3.60	$412.30
1972	148.50	5.02	157.80	0.00	0.00	97.38	0.00	0.00	3.60	$412.30
1973	136.13	5.02	148.52	0.00	0.00	116.85	0.00	0.00	3.60	$410.11
1974	49.50	5.02	148.52	0.00	0.00	116.85	40.01	24.33	3.60	$387.82
1975	49.50	5.02	148.52	0.00	0.00	116.85	40.01	24.33	3.60	$387.82
1976	24.75	5.02	148.52	0.00	0.00	126.59	53.34	24.33	3.60	$386.15
1977	0.00	5.02	148.52	0.00	0.00	136.33	80.01	18.25	3.60	$391.72
1978	0.00	5.02	157.80	0.00	0.00	155.80	80.01	0.00	3.60	$402.23
1979	0.00	5.02	157.80	0.00	0.00	155.80	80.01	0.00	3.60	$402.23
1980	0.00	5.02	148.52	0.00	0.00	146.06	106.68	0.00	3.60	$409.88
1981	12.38	5.02	139.24	0.00	0.00	146.06	106.68	0.00	3.60	$412.97
1982	12.38	5.02	139.24	0.00	0.00	146.06	106.68	0.00	3.60	$412.97
1983	12.38	5.02	139.24	0.00	0.00	146.06	106.68	0.00	3.60	$412.97
1984	12.38	5.02	139.24	0.00	0.00	146.06	106.68	0.00	3.60	$412.97

Appendix Table 21

LEVELS 3-4: ANNUAL COSTS OF FUNGICIDES ON APPLES IN ONTARIO ($/Ha)

YEAR	dodine	dichlone	captan	microfine sulfur	phenyl mercury	polyram	dikar	benomyl	other	Annual Costs
1965	207.90	8.37	213.50	14.59	23.84	0.00	0.00	0.00	18.00	$486.19
1966	173.25	8.37	204.22	7.82	20.44	77.90	0.00	0.00	9.00	$500.98
1967	178.20	8.37	202.36	0.00	20.44	97.38	0.00	0.00	9.00	$515.73
1968	210.38	8.37	185.65	0.00	17.03	97.38	0.00	0.00	9.00	$527.80
1969	210.38	8.37	185.65	0.00	17.03	87.64	0.00	0.00	9.00	$518.06
1970	123.75	5.02	157.80	0.00	8.52	95.43	0.00	0.00	5.40	$395.91
1971	148.50	5.02	157.80	0.00	0.00	97.38	0.00	0.00	3.60	$412.30
1972	148.50	5.02	157.80	0.00	0.00	97.38	0.00	0.00	3.60	$412.30
1973	136.13	5.02	148.52	0.00	0.00	116.85	0.00	0.00	3.60	$410.11
1974	49.50	5.02	148.52	0.00	0.00	116.85	40.01	24.33	3.60	$387.82
1975	37.13	3.35	142.95	0.00	0.00	111.01	32.00	18.25	3.60	$348.28
1976	12.38	3.35	148.52	0.00	0.00	109.06	53.34	18.25	3.60	$348.49
1977	0.00	3.35	139.24	0.00	0.00	126.59	66.68	13.38	3.60	$352.83
1978	0.00	3.35	141.09	0.00	0.00	136.33	80.01	0.00	3.60	$364.38
1979	0.00	3.35	141.09	0.00	0.00	136.33	80.01	0.00	3.60	$364.38
1980	0.00	3.35	137.38	0.00	0.00	136.33	85.34	0.00	3.60	$366.00
1981	4.95	3.35	129.96	0.00	0.00	136.33	90.68	0.00	3.60	$368.85
1982	4.95	3.35	129.96	0.00	0.00	136.33	90.68	0.00	3.60	$368.85
1983	4.95	3.35	129.96	0.00	0.00	136.33	90.68	0.00	3.60	$368.85
1984	4.95	3.35	129.96	0.00	0.00	136.33	90.68	0.00	3.60	$368.85

APPENDIX

Table 22

Number of Pesticide Applications by Pest Control Level on Apples in Ontario from 1965 to 1984

Year	Level 1	Level 2	Levels 3-4
1965	16.50	16.50	16.50
1966	16.45	16.45	16.45
1967	16.25	16.25	16.25
1968	16.25	16.25	16.25
1969	16.00	16.00	16.00
1970	16.00	12.00	11.50
1971	16.00	12.00	11.25
1972	16.00	12.00	11.00
1973	16.00	12.00	11.00
1974	16.00	11.50	11.00
1975	16.00	11.50	10.00
1976	16.00	11.50	10.00
1977	16.00	11.50	10.00
1978	16.00	11.50	10.00
1979	16.50	11.50	10.00
1980	17.00	11.00	10.00
1981	17.00	12.25	10.50
1982	17.00	12.50	10.75
1983	17.00	13.00	11.00
1984	17.00	13.25	11.00
Total	326.95	260.45	240.45

Source: Roberts, 1984

APPENDIX

Table 23

Cost of Applications by Pest Control Level on Apples in Ontario from 1965 to 1984 ($/HA)

Year	Level 1	Level 2	Levels 3-4
1965	610.50	610.50	610.50
1966	608.65	608.85	608.65
1967	601.25	601.25	601.25
1968	601.25	601.25	601.25
1969	592.00	592.00	592.00
1970	592.00	444.00	425.50
1971	592.00	444.00	416.25
1972	592.00	444.00	407.00
1973	592.00	444.00	407.00
1974	592.00	425.50	407.00
1975	592.00	425.50	370.00
1976	592.00	425.50	370.00
1977	592.00	425.50	370.00
1978	592.00	425.50	370.00
1979	610.50	425.50	370.00
1980	629.00	407.00	370.00
1981	629.00	453.25	388.50
1982	629.00	462.50	397.75
1983	629.00	481.00	407.00
1984	629.00	490.25	407.00
Total	12,097	9,637	8,897

APPENDIX

Table 24

Total Cost ($/HA) of Pest Control on Apples in Ontario from 1965 to 1984

Year	Level 1	Level 2	Levels 3-4
1965	1443.94	1443.94	1443.94
1966	1518.04	1518.04	1518.04
1967	1481.24	1481.24	1481.24
1968	1554.47	1554.47	1554.47
1969	1474.32	1474.32	1474.32
1970	1678.63	1266.58	1177.59
1971	1893.04	1301.37	1167.87
1972	1774.49	1188.09	1066.74
1973	1760.67	1223.24	1083.22
1974	1661.74	1071.27	1038.91
1975	1686.91	1108.61	962.06
1976	1693.56	1139.10	963.94
1977	1588.83	1063.04	943.55
1978	1643.78	1122.38	963.42
1979	1714.10	1097.16	968.69
1980	1780.43	1077.44	963.82
1981	1751.98	1158.80	1007.89
1982	1756.47	1218.45	1027.97
1983	1748.98	1279.52	1067.80
1984	1748.98	1307.43	1067.80
Total	33,355	25,094	22,943